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CBSKY4: REFERENCE MANUAL

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ABSTRACT *(Maximum 200 words)*
The CBSKY4 component to the Celestial Background Scene Descriptor (CBSD) provides positions and fluxes for over 10,000 cataloged stars and stars produced by a statistical number density (logN-logS). Wavelength coverage is from 2 to 30 μm plus the Johnson BVJHK bands, the COBE/DIRBE 2.4μm band, IRAS 12 and 25μm, TD1A 1565 Å, FAUST 1660 Å, and the Apollo 16 "S201" 1400 Å band. Spectral energy distributions of all stars are provided through 87 spectral templates. The model provides images over the entire sky and rectangular or gnomonic projection images of narrower fields of view. Output files give statistics in the scene. The user provides the time, look angles, band parameters (predefined band, response function, or an upper and lower limit), and image size requirements. This document is a users guide to the CBSKY4 model.

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Table of Contents

List of Figures

List of Tables

1. Introduction

The emissions from stellar point sources represent the most important source of clutter in the celestial background. The CBSKY4 component of the Celestial Background Scene Descriptor (CBSD) produces radiance maps or images of the distribution of point sources and the irradiance of the celestial sky. The CBSKY4 module achieves this by using a combination of in-band flux estimates of bright stars listed in star catalogs and statistically generated stars (Wainscoat et al. 1992) based on expected stellar densities for each location in the sky. The in-band estimates are based on the use of calibrated spectral templates such that each star modeled is assigned a spectral template best matching its energy distribution. Options to include the under-represented star counts in the major star forming regions as indicated by CO (Dame et al. 1987) and to exclude star counts in dark regions are provided (Cohen 1994). The output image and statistics can be customized to fit a variety of applications. The images created have user-defined bandpasses between 2 and 30 μm, array dimensions, map projections, coordinate systems, and units. Below 2 μm individual bands are used, such as the Johnson BVJHK photometric bands, to provide UV to 30 μm coverage.

Bright stars are tabulated in a catalog described by Right Ascension and Declination (J2000), magnitude, and spectral class. The stellar catalog used in CBSKY4 is derived from:

- 9000+ sources from the Yale Bright Star Catalog (Hoffleit and Warren 1991)
- 2503 sources from the IRAS Point Source Catalog (Walker and Cohen 1992)
- 49 sources from the MSX Infrared Point Source Catalog (Egan et al. 1999)

If we could catalog all the stars in the Milky Way Galaxy, there would be over 400 million stars. Even though several large databases of stellar position exist they are not suitable for inclusion into CBSKY4 because of the lack of spectral information. Therefore, to supplement the star catalogs and extend CBSKY4 to fainter sources, a spatial and statistical distribution of stars is generated by the SKY model (Wainscoat et al. 1992, Cohen 1993, 1994). The SKY model is a detailed model for the infrared point source sky that comprises geometrically and physically realistic representations of the obvious galactic components. Features that are modeled include:

- The galactic disk
- The bulge
- The spheroid
- The spiral arms (including the 'local arm')
- The molecular ring, and
- The extragalactic sky (distant galaxies).

These features, shown in Figure 1, comprise the bulk of the known galaxy.

CBSKY4 produces output for user-specified regions of the sky. A region is defined by its central stare point, the array size, the pixel size (instantaneous field-of-view), and the arbitrary bandpass.

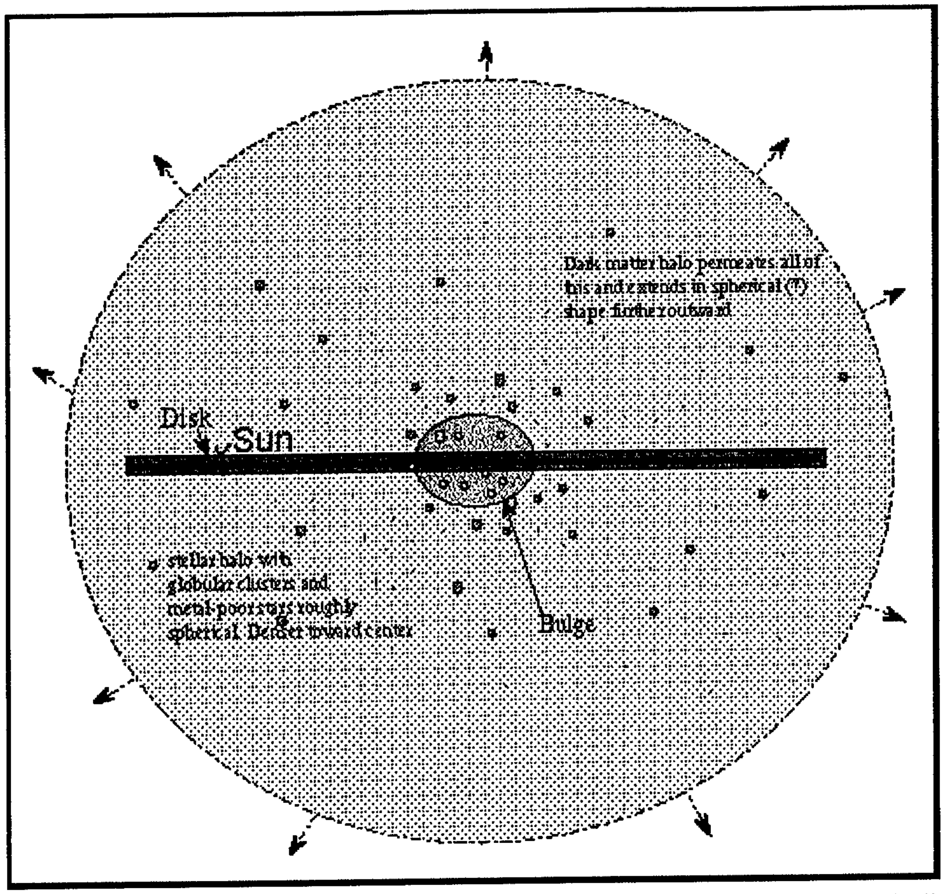


Figure 1: Sketch of the Galaxy with components labeled and position of Sun indicated.

2. Some Definitions

CBSKY produces radiance maps or images of the distribution of point sources. This section serves as a brief introduction to stellar observations and provides definitions of relevant terms.

2.1 Coordinate Systems

The CBSKY4 central stare point can be defined in galactic coordinates, ecliptic coordinates, equatorial coordinates, or horizon (altitude/azimuth) coordinates and reckoned to B1950, J2000, or the mean equinox and epoch of the observation date.

The locations of objects in the sky are defined by celestial coordinates analogous to the terrestrial latitude/longitude system. Astronomers have defined many systems, suitable for different purposes. The systems, typically centered on the Earth, the observer, or the Sun, are spherical coordinate systems. Each system is defined by a *fundamental circle* and a *fixed point on it.* The fundamental circle lies in the x-y plane. It is in this plane that the longitude angle is measured referenced to some fixed point. The latitude is the measure of elevation above/below the fundamental circle. The four coordinate systems used in CBSKY4 (galactic, ecliptic, equatorial, and horizon) are briefly described in Table 1.

2.2 Units of Radiated Energy

The images produced by CBSKY4 represent the power at the focal plane of an optical instrument in the defined passband and can include the optics/sensor spectral response function (filter function). The various radiation terms can be used rather loosely in the literature. Here we define radiance (L) as the power emitted by a unit surface area (dA_s) into a unit solid angle ($d\Omega_s$) with the units of W cm^{-2} sr^{-1}. Irradiance (F) is the power received by a surface area (dA_o) from a unit solid angle ($d\Omega_o$) and also has units of W cm^{-2} sr^{-1}. Spectral radiance (L_λ) and spectral irradiance (F_λ) are the radiance and irradiance, respectively, in a unit spectral interval and have units of W cm^{-2} sr^{-1} μm^{-1}. Flux (Φ) then is the total power (energy per unit time), in W, falling on a surface. Flux density ($d\Phi/dA$) is the power per unit area and is measured in W cm^{-2} and spectral flux density ($d\Phi_\lambda/dA$) is the power per unit area per unit spectral interval measured in W cm^{-2} μm^{-1}. We then can define the fundamental equation of radiation transfer for a differential element of power for the source, s, and observer, o, separated by a distance r:

$$d\Phi = L\frac{dA_s \cos\theta_s dA_o \cos\theta_o}{r^2}$$

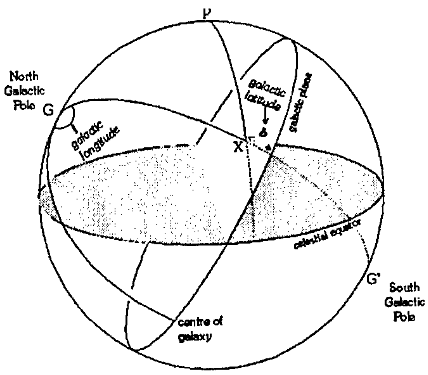
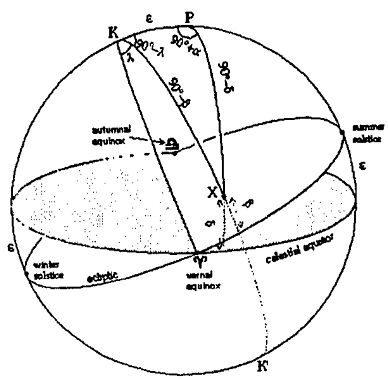
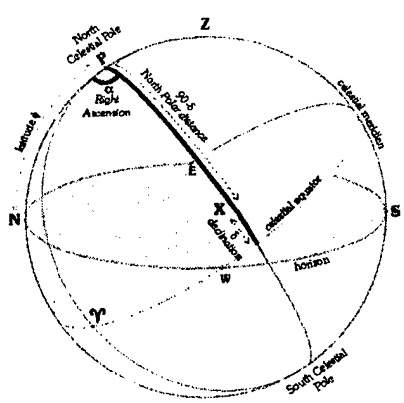
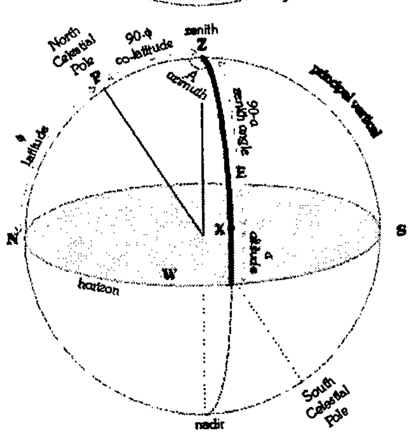
where θ is the angular distance from the surface normal. For our purposes we take $\theta = 0$.

It is also instructive to define the flux density in terms of Jansky's (Jy) where 1 Jy = 10^{-26} W m^{-2} Hz^{-1}. For an in-band irradiance with a response function r_λ we define the irradiance at 1 Jy as:

$$F(1\,\mathrm{Jy}) = \frac{10^{-26}c}{\lambda_{eff}} \int f_\lambda r_\lambda d\lambda \quad [\mathrm{W\,cm^{-2}}]$$

with λ in μm and c is the speed of light.

Table 1: Description of coordinate systems used in astronomical observations.

System		Description	Coordinates
Galactic		An earth-centered spherical coordinate system, with the x-y plane in the plane of the galaxy, and the x-axis pointing to the assumed center of the galaxy.	Longitude, *l*, is the angle measured in the plane of the galaxy from the center of the galaxy. Latitude, *b*, is the elevation angle above or below the plane of the galaxy. Galactic coordinates are referenced only to the epoch B1950.
Ecliptic		An earth-centered spherical coordinate system with the x-y plane in the plane of the ecliptic (Earth's orbit around the Sun) and the x-axis pointing to the equinox point.	Longitude, λ, is the angle measured in the plane of the ecliptic from the Vernal equinox (Aries point). Latitude, β, is the elevation angle above or below the plane of the ecliptic.
Equatorial		An earth-centered spherical coordinate system, with the x-y plane in the plane of the Earth's equator, and the x-axis pointing to the equinox point. The equatorial coordinate system is a reflex of the Earth's longitude and latitude system.	Longitude, more commonly called the Right Ascension, RA (α), is measured in the plane of the equator from the Vernal equinox (Aries point). By tradition, Right Ascension is reported in hours rather than degrees. Latitude, more commonly called Declination, Dec (δ), is the elevation angle above or below the equator.
Horizon		An earth-surface-observer-based spherical coordinate system with the horizon as the x-y plane and the z-axis pointing along the observer zenith.	The azimuth is the angular distance in the horizon plane measured in degrees clockwise from due North. The altitude angle is the elevation above the horizon plane, objects below the horizon have a negative altitude. Alternatively, the zenith angle is the angle measure from the zenith towards the horizon.

The effective wavelength is defined in terms of the source function f_λ (e.g., a blackbody):

$$\lambda_{eff} = \frac{\int \lambda f_\lambda r_\lambda d\lambda}{\int f_\lambda r_\lambda d\lambda}$$

which assuming λf_λ is a constant (Beichman et al. 1988, p VI.-27) reduces to:

$$\lambda_{eff} = \frac{\int r_\lambda d\lambda}{\int r_\lambda / \lambda \, d\lambda}$$

and the flux at 1 Jy is:

$$F(1\,\mathrm{Jy}) = \frac{10^{-26} c}{\lambda_{eff}} \int r_\lambda / \lambda \, d\lambda \quad [\mathrm{W\,m^{-2}}]$$

We further define the bandwidth as (again assuming λf_λ = constant):

$$\Delta\lambda = \int \lambda f_\lambda r_\lambda d\lambda = \int r_\lambda d\lambda$$

All point sources in CBSKY4 are characterized in terms of flux density in W m^{-2}. We can now define the conversions between the different radiometric units in the CBSKY4 model that users may find useful (Table 2). By including the projected are of the sensor IFOV ($\Delta\Omega$) we can also define the irradiance values. The different radiometric units are selected by an input parameter and converted internally by the code.

Table 2: Radiometric Conversion Factors.

Radiometric Unit	Units	Multiple by	CBSKY4 Unit Input
Flux density	W cm^{-2}	1	W/CM2
Flux density	Jy	$\Delta\lambda^{-1}$ $F(1\,\mathrm{Jy})^{-1}$	JY
Spectral Flux Density	W cm^{-2} μm^{-1}	$\Delta\lambda^{-1}$	W/CM2/MICRON
Irradiance	W cm^{-2} sr^{-1}	$\Delta\Omega^{-1}$	W/CM2/SR
Spectral Irradiance	W cm^{-2} μm^{-1} sr^{-1}	$\Delta\lambda^{-1}$ $\Delta\Omega^{-1}$	W/CM2/MICRON/SR
Spectral Irradiance	Jy sr^{-1}	$\Delta\lambda^{-1}$ $F(1\,\mathrm{Jy})^{-1}$ $\Delta\Omega^{-1}$	JY/SR

2.3 Apparent Magnitude of Stars

In addition to the radiometric values, catalog output of CBSKY4 can be in apparent magnitudes. The apparent brightness depends on the luminosity and the distance from the observer to the star. Apparent magnitude is a quantified scale for describing apparent brightness. Figure 2 shows a rough scale indicating the range from brightest to faintest objects.

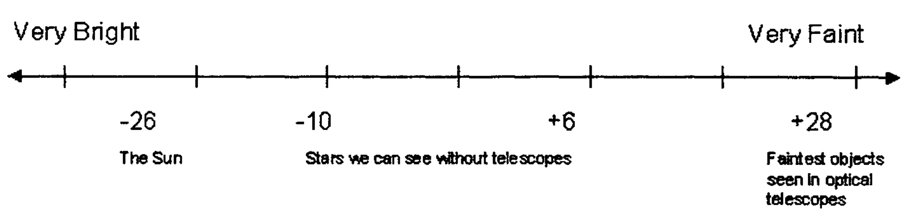


Figure 2: Number line of astronomical magnitude system.

The use of (apparent) magnitudes dates back to antiquity. Ancient astronomers, like Hipparchus, made catalogues of stars that included a perceived brightness value. Modern stellar photometry is attributed to N. Pogson's (1856) definition of the magnitude scale and J. C. F. Zollner's invention of the visual photometer (Budding 1993). Using Zollner's photometer, the brightness of a star could be compared to the brightness of an artificial star image using prisms.

Pogson's definition relates the fluxes, F_1 and F_2, from two different stars to their difference in magnitude. We will follow the definitions of magnitude to flux conversion given in Price and Murdock (1985) and Wainscoat et al. (1992), namely:

$$m_1 - m_2 = -2.5\log\left(\frac{F_1}{F_2}\right) \quad \text{[mag]}$$

or,

$$\frac{F_1}{F_2} = 10^{-0.4(m_1 - m_2)}$$

meaning a magnitude difference of 5 has a flux ratio of 100 and, therefore, a difference of 1 magnitude has a flux ratio of ~2.512.

The use of magnitudes is, in part, for historical reasons but is also from convenience. Since flux values span a large dynamic range, magnitudes are a convenient way to logarithmically condense the flux into manageable bins. It is common to define the flux of the reference object (F_2) in such a way that the magnitude, m_2, is identically zero. F_2 is then defined to be the flux at magnitude zero or the zero point. Simplifying:

$$m = -2.5\log\left(\frac{F}{F_0}\right)$$

with F_0 being the flux at magnitude zero (some values of F_0 are tabulated in Section 8), and F being the flux of the star, the magnitude, m, of the star can be computed. Conversely, the flux can be computed from the magnitude:

$$F = F_0 \cdot 10^{-0.4m}$$

Magnitudes are defined for their reference spectral band defined by the filter function of the detector system and referenced to the effective wavelength. Typically, this is the wavelength of maximum-sensitivity or the center of the band. The visual magnitude, m_V, is defined by the sensitivity of the human eye times the transmission of the instrument. The human eye has a sensitivity maximum at about 540 nm (green visible light). Photographic magnitudes, m_{pg}, have a peak around 420 nm.

Cataloged stars have apparent magnitudes measured at different effective wavelengths, and it is important for catalogue users to understand how these apparent magnitudes have been defined. Astronomers have developed standard systems for the determination of stellar magnitudes. The UBV System developed by H. L. Johnson and W. W. Morgan (1951, 1953) has current widespread use. Here the U is the ultraviolet magnitude, also designated m_U, measured at 365 nm. V is the visible magnitude, m_V, measured at 548 nm. B is the blue magnitude, m_B, measured at 440 nm. Kron and Smith (1951), Low and Johnson (1962), and Johnson (1965a, 1965b) have extended the UBV System into the red and infrared by adding the filters of Table 3.

Table 3: Effective Wavelengths for the Johnson Bands

Band	Effective Wavelength
U	365 nm
B	440 nm
V	548 nm
R	0.7 μm
I	0.9 μm
J	1.25 μm
H	1.63 μm
K	2.2 μm
L	3.6 μm
M	5.0 μm
N	10.6 μm
Q	21.0 μm

Other color systems have been developed. The narrow bandwidth photometry developed by Strömgren (1966) is often used for spectral classification (Table 4).

Table 4: Effective Wavelengths for Stromgren Photometry

Band	Sensitivity-Maximum Wavelength
u	350 nm
b	411 nm
v	467 nm
y	547 nm

In CBSKY4, users can specify their own bandpass, supply a filter function file, or select a predefined filter of Tables 5 & 6 (Cohen 1994). The flux at magnitude zero value is predefined for the predefined filters and is calculated if the user specifies an arbitrary bandpass. The following two tables list the standard bands available and their attributes. Section 8 provides the flux at magnitude zero and other parameters for the filter files included in the CBSKY4 distribution.

Table 5: Effective Wavelengths for CBSKY4 Pre-defined Bands

Band (inputs to CBSD)	**Effective Wavelength**	**Standard**
1400A	1400Å	1400Å ultraviolet channel Apollo 16 "S201"
1565A	1565Å	TD1 1565Å ultraviolet channel
1660A	1660Å	FAUST 1660Å ultraviolet channel
B	0.44μm	standard B photometric band (0.44μm)
V	0.55μm	standard V photometric band (0.55μm)
J	1.25μm	standard J photometric band (1.25μm)
H	1.65μm	standard H photometric band (1.65μm)
K	2.22μm	standard K photometric band (2.22μm)
2.4um	2.4μm	COBE 2.4μm bandpass
12um	12μm	IRAS 12μm bandpass
25um	25μm	IRAS 25μm bandpass

Table 6: Parameters for CBSKY4 Pre-defined Bands

Filter	**Bandwidth (μm)**	**band_center (μm)**	**flux_mag_zero (Jy)**	**flux_mag_zero (W/m^{2})**
B	0.098	0.44	6.61E-12	6.47E-09
V	0.089	.55	3.80E-12	3.38E-09
J	0.24	1.25	3.31E-13	7.95E-10
H	0.32	1.65	1.16E-13	3.71E-10
K	0.4	2.22	3.98E-14	1.59E-10
2.4 μm	0.09	2.4	2.80E-14	2.52E-11
12 μm	6.47	12	8.5541E-17	5.539E-12
25 μm	10.75	25	4.5575E-18	4.903E-13
1565 Å		1565 Å	3.388E-12	1.118E-9
1400 Å		1400 Å	9.043E-12	2.44E-9
1660 Å		1660 Å	3.388E-12	1.044E-9

2.4 Absolute Magnitudes of Stars

The luminosity or absolute brightness of a star is the amount of energy created by the star, independent of the distance to the star. The absolute magnitude is a measure of the energy produced by a star or object. It is defined as the apparent magnitude of the star if the star were located at a standard distance of 10 parsecs (3.086×10^{17} m) from the observer. Absolute magnitudes can be inferred from the spectrum of a star.

Apparent magnitude values are the result of both the intrinsic brightness of the star (which is related to its internal energy production) and the effect of distance (which has nothing to do with the intrinsic structure of the star). The inverse square law of brightness can be used to infer distances to stars. The difference between the absolute magnitude, *M*, and the apparent magnitude, *m*, is called the distance modulus (*m* - *M*). The formula:

$$m - M = 5.0\log(D/10.0)$$

where D is the distance between the observer and the object in parsecs. If the distance to the star is known, then the absolute magnitude can be found. If the star's distance is not known then its absolute magnitude has to be inferred from some other measure. Table 7 gives apparent and absolute magnitudes for commonly known astronomical objects.

Table 7: Comparison of Apparent and Absolute Magnitudes

Object	Apparent Visual Magnitude	Absolute Magnitude
The Sun	-26.8	4.8
100 Watt Bulb at 3 m	-17.1	66.3
Full Moon	-12.5	32
Venus (at brightest)	-4.4	28
Sirius (brightest star)	-1.5	1.4
Alpha Centauri (closest star)	-0.04	4.4
Andromeda Galaxy (farthest naked eye object)	3.5	-21
Faintest naked eye stars	6-7	------
Faintest star visible from Earth telescopes	~25	------

2.5 Spectral Classes of Stars

Historically, the classification of stellar spectra resulted from the discovery of absorption lines by Fraunhofer, Kirchhoff, and Bunsen (Karttunen et al. 1996). Observations made it clear that stellar spectra can be ordered in a one-dimensional series. An attempt was made to order the stellar spectra by the number of lines but starting with the strongest lines of Hydrogen. In the 1880s, Pickering was developing the Henry Draper Memorial, a catalog of stellar positions by Henry Draper but including a classification of the stellar spectra (Pickering 1897, Pickering and Fleming 1897, Maury and Pickering 1897). Stars with the strongest hydrogen absorption were given the type A. However the initial classification was not based on temperature.

A newer classification system was developed by Annie Jump Cannon based on the complexity of the spectra but retaining many of the original letter designations (Cannon and Pickering 1907). The Harvard types, with some later enhancements and additions, are our current basis of spectral classification (Table 8).

The OBAFGKM series is a quantification system that is now known to be ordered by decreasing temperature. In addition to each broad color class designated by a letter, there are subclasses 0 through 9 (excepting O) from letters going left to right. Thus, a B5 star is between B0 and A0 a B9 is slightly hotter than an A0. A star is classified on the basis of the degree to which its spectrum matches a spectrum of one of the standard stars.

Table 8: Harvard Types

hotter	→					cooler
						S
O	B	A	F	G	K	M
					R	N
blue		yellow			red	

Further, in the year 1912, the understanding of stellar spectral classification was revolutionized when Ejner Hertzsprung and later H. N. Russell (1913) constructed a scatter plot of spectral types and absolute magnitudes of all stars in which the parameters were well known. They found that most stars populate a narrow band, called the main sequence, which stretches diagonally from the bright blue-white B and A stars through the yellow stars and out to the faint red stars. Therefore, by obtaining a star's spectral classification its absolute magnitude could be deduced.

CBSKY4 requires a spectral energy plot (spectrum) for each star. Since a spectrum is not available a few standard spectral types were defined as spectral templates independent of distance. Each star of the same spectral type has the same spectrum that is modified by distance and extinction. CBSKY4 uses 87 spectral templates. The spectral templates used by CBSKY4 are those developed by Walker and Cohen (1992). Walker and Cohen defined their spectral classification system for the program SKY which models the counts per magnitude bin for an arbitrary line-of-sight at any location in the sky and includes 87 spectra templates from 2 to 30 µm. Each star, either catalog or statistically generated, is assigned to one of the 87 classes based on which template best matches the star's spectrum as mapped in Table 9. The spectral templates were generated by model runs from the Kurucz's (1970, 1979) ATLAS stellar atmosphere model and tied to observational data (Cohen et al. 1995, 1996).

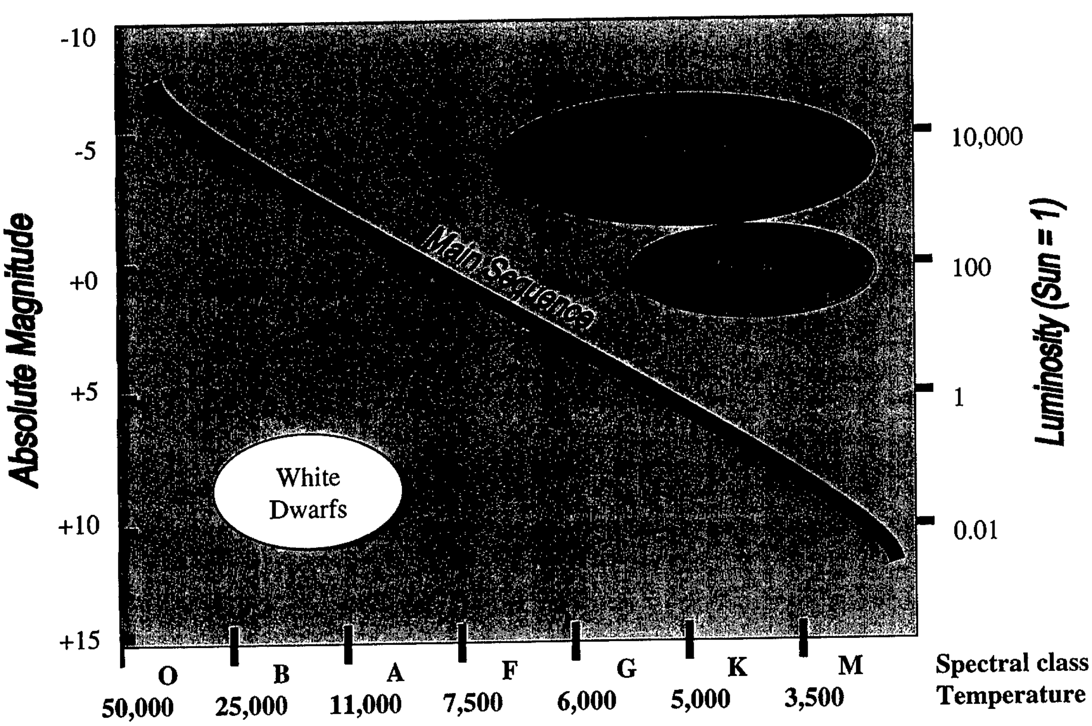


Figure 3: Hertzsprung-Russell diagram

Table 9: SKY4 Spectral Types.

Spectral Template	Related Spectral Type	Spectral Template	Related Spectral Type	Spectral Template	Related Spectral Type
1	B0,1 V	30	YOUNG OB	59	AGB C 25
2	B2,3 V	31	A-G I-II	60	AGB CI 01
3	B5 V	32	K-M2 I-II	61	AGB CI 03
4	B8-A0 V	33	M3-4 I-II	62	AGB CI 05
5	A2-5 V	34	AGB M 01	63	AGB CI 07
6	F0-5 V	35	AGB M 03	64	AGB CI 09
7	F8 V	36	AGB M 05	65	AGB CI 11
8	G0-2 V	37	AGB M 07	66	AGB CI 13
9	G5 V	38	AGB M 09	67	AGB CI 15
10	G8-K3 V	39	AGB M 11	68	AGB CI 17
11	K4-5 V	40	AGB M 13	69	AGB CI 19
12	M0-1 V	41	AGB M 15	70	AGB CI 21
13	M2-3 V	42	AGB M 17	71	AGB CI 23
14	M4-5 V	43	AGB M 19	72	AGB CI 25
15	M late V	44	AGB M 21	73	AGB CI 27
16	F8-G2 III	45	AGB M 23	74	AGB CI 29
17	G5 III	46	AGB M 25	75	AGB CI 31
18	G8 III	47	AGB C 01	76	X 1E
19	K0,1 III	48	AGB C 03	77	X 1A
20	K2,3 III	49	AGB C 05	78	X 2
21	K4,5 III	50	AGB C 07	79	X 3
22	M0 III	51	AGB C 09	80	X 4
23	M1 III	52	AGB C 11	81	X 5
24	M2 III	53	AGB C 13	82	PN BLUE
25	M3 III	54	AGB C 15	83	PN RED
26	M4 III	55	AGB C 17	84	RN BLUE
27	M5 III	56	AGB C 19	85	RN RED
28	M6 III	57	AGB C 21	86	H II REG
29	M7 III	58	AGB C 23	87	T TAURI

3. CBSKY4 Description

3.1 Modeling Stars Using Star Catalogs

3.1.1 The IRAS Point Source Catalog

Data collected by the IRAS (the Infrared Astronomical Satellite) is tabulated in a catalog of point sources. IRAS surveyed the entire sky, and the IRAS point source catalog contains 246,000 objects. For many applications, model imagery can be generated by placing point sources of known Right Ascension, Declination, and magnitude into an array of prescribed band-pass, look-angles, and IFOV. However, the IRAS's spectral coverage was limited to 12 and 25μm. Used alone, this is not broad enough for CBSD's requirement of 0.2 to 35μm dial-a-wavelength modeling. Furthermore, the large pixel size of IRAS limits the flux of individual sources and under-samples the star count in the densest parts of the sky (the galactic plane and the Magellanic Clouds). For inclusion into CBSD, the brightest 2503 stars were selected and assigned a spectral type using SKY's 87 spectral types classification system.

3.1.2 The MSX Stars (A Supplement to Missing IRAS Regions)

The IRAS survey under-samples high density star regions such as the galactic plane and the Magellanic Clouds. Furthermore, there are two large gaps in the survey data. To supplement the IRAS point sources, bright stars have been cataloged from MSX observations (Table 10). The 49 stars brighter than 32 Jy in SPIRIT III Band C were used to create the catalog (Egan et al. 1999). The star name is the MSX catalog name, coordinates are J2000. d is the average of the distance and σ is the standard deviation of the 4 distance estimates in pc, m_C is the MSX SPIRIT III Band C magnitude. Each star was assigned a spectral type using The SKY model's system. To do the assignment, a "best fit temperature" was computed for each of SKY's 87 classes. Then the temperature of the MSX star was estimated based on its measured radiance values. The temperature was mapped into the closest best fit temperatures of SKY's classes to assign the MSX star a spectral class (and absolute magnitude). Since both the absolute and apparent magnitudes were assigned, a unique addition to this star catalog is the estimate of the distance to the star. Figure 4 maps the distribution of these 49 MSX stars in the sky.

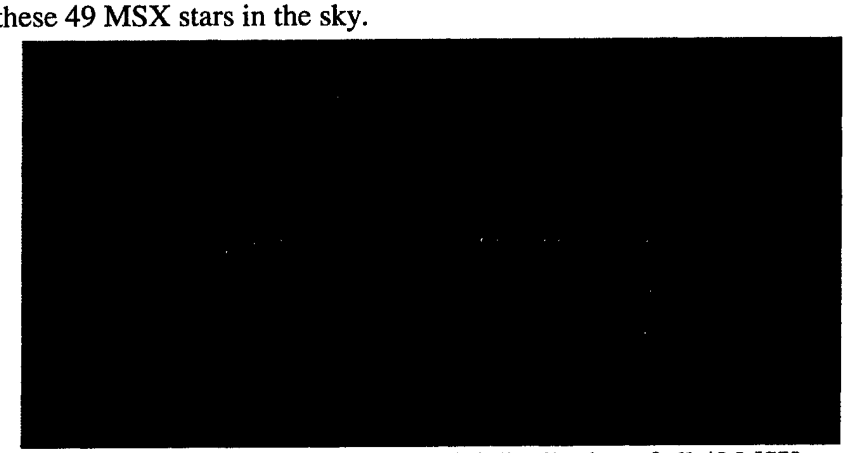


Figure 4: An all sky image shows the spatial distribution of all 49 MSX stars as they appear at 12 μm.

Table 10: The MSX stars. The 49 stars brighter than 32 Jy in SPIRIT III Band C.

Star Name	RA (°)	Dec (°)	Spectral Type		d (pc)	σ (pc)	m_C
MSX5C_G339.5581-00.4009	251.7715	-45.8426	38	AGBM09	280.1	24.7	-2.689
MSX5C_G008.9338-00.0150	271.3986	-21.2282	41	AGBM15	2285.1	161.9	-2.060
MSX5C_G067.8975-00.3709	300.9107	30.4692	39	AGBM11	809.9	76.2	-1.866
MSX5C_G030.8238-00.1566	282.0374	-1.9475	67	AGBCI15	2420.8	198.2	-1.671
MSX5C_G286.4814+00.0518	159.9822	-58.5553	41	AGBM15	3397.5	133.0	-1.139
MSX5C_G339.5324-00.4157	251.7638	-45.8718	80	X4	15695.6	1019.5	-1.383
MSX5C_G305.4013+00.0170	198.2593	-62.7512	36	AGBM05	173.3	11.2	-0.744
MSX5C_G305.3616+00.0562	198.1658	-62.7154	60	AGBCI01	507.6	70.7	-0.708
MSX5C_G036.7133+00.2023	284.4055	3.4574	54	AGBC15	489.0	40.4	-1.453
MSX5C_G333.0581-00.1018	244.8118	-50.4060	70	AGBCI21	557.7	50.2	-1.413
MSX5C_G014.5522-00.0084	274.2522	-16.3015	55	AGBC17	875.6	44.9	-0.373
MSX5C_G317.2083+00.2337	221.8239	-59.3881	39	AGBM11	1245.7	91.2	-0.861
MSX5C_G312.2166+00.1341	212.4998	-61.3134	66	AGBCI13	2049.1	120.3	-1.186
MSX5C_G340.0427-00.0923	251.8830	-45.2735	55	AGBC17	896.2	52.3	-0.315
MSX5C_G025.8160-00.0513	279.6475	-6.3532	80	X4	23021.4	1660.4	-0.607
MSX5C_G354.0050+00.2882	262.3517	-33.8419	80	X4	24819.4	2158.4	-0.417
MSX5C_G014.5154+00.0385	274.1909	-16.3115	67	AGBCI15	4708.9	652.4	-0.305
MSX5C_G079.7530+00.4934	308.2547	40.7606	36	AGBM05	100.8	8.1	-2.017
MSX5C_G079.6430+00.4726	308.1906	40.6598	29	M7III	551.9	31.6	-1.969
MSX5C_G267.0501+00.4904	135.6141	-45.8209	49	AGBC05	590.3	33.2	-0.254
MSX5C_G340.3332-00.5626	252.6609	-45.3531	67	AGBCI15	2996.2	343.6	-1.248
MSX5C_G087.2713-01.4394	316.8337	45.3505	53	AGBC13	623.5	57.2	-0.801
MSX5C_G171.5549-01.3804	79.5791	35.2493	47	AGBC01	524.5	25.6	-0.241
MSX5C_G085.9296-02.0772	316.2323	43.9284	25	M3III	121.0	5.4	-0.299
MSX5C_G355.8623-02.9847	266.8822	-34.0203	36	AGBM05	144.9	9.6	-1.156
MSX5C_G084.9302-03.4953	316.7564	42.2370	83	PNRED	191.5	19.0	-2.759
MSX5C_G024.2254-03.4539	281.9724	-9.3199	39	AGBM11	1224.2	80.9	-0.871
MSX5C_G027.6072+01.9718	278.6689	-3.8332	29	M7III	798.4	51.2	-1.190
MSX5C_G338.3721+01.9446	248.1457	-45.1699	61	AGBCI03	622.5	23.0	-0.479
MSX5C_G344.5464+01.0934	254.5392	-41.0380	76	X1E	4607.0	246.0	-1.469
MSX5C_G313.4184+01.2131	214.1430	-59.9140	29	M7III	412.0	38.0	-2.821
MSX5C_G012.2183+00.9084	272.2392	-17.9096	54	AGBC15	768.1	58.0	-0.527
MSX5C_G087.0278+00.5172	314.4977	46.4670	36	AGBM05	113.2	10.1	-1.735
MSX5C_G334.5499+03.8845	242.2980	-46.4895	76	X1E	5985.2	463.4	-0.905
MSX5C_G091.8185+03.1660	316.2933	51.8115	63	AGBCI07	441.2	19.6	-2.320
MSX5C_G265.9367+02.8201	136.9996	-43.4346	23	M1G	39.0	2.3	-1.865
MSX5C_G135.5837+02.9998	41.6675	63.0056	37	AGBM07	447.5	25.2	-0.379
MSX5C_G086.0266-06.5309	320.7021	40.9332	52	AGBC11	402.9	24.9	-1.331
MSX5C_G075.1849-33.1836	333.0671	14.5527	53	AGBC13	478.7	37.3	-1.326
MSX5C_G083.6611-10.1747	321.8679	36.6989	80	X4	14728.1	1268.5	-1.585
MSX5C_G082.0072-14.4347	324.0669	32.5173	50	AGBC07	587.8	40.6	-0.227
MSX5C_G071.9082-34.2596	331.8183	11.8869	36	AGBM05	120.3	9.3	-1.737
MSX5C_G341.2563-73.5115	359.6844	-39.4495	36	AGBM05	72.4	5.7	-2.776
MSX5C_G062.1914-55.7326	343.1537	-7.5798	23	M1III	59.3	2.9	-0.928
MSX5C_G182.7838+72.0229	173.8768	34.8674	54	AGBC15	404.8	28.4	-1.909
MSX5C_G257.5943+23.5781	147.7660	-23.0153	63	AGBCI07	911.2	89.6	-0.831
MSX5C_G233.0251+59.4254	163.4060	13.7133	53	AGBC13	768.2	57.9	-0.372
MSX5C_G262.5925+18.5164	147.7849	-29.8971	53	AGBC13	709.1	64.3	-0.499
MSX5C_G256.2850+33.8804	154.2523	-14.6572	35	AGBM03	57.1	12.9	-2.689

3.1.3 The Yale Bright Star Catalog

The YBSC (Hoffleit and Warren 1991) was also formatted for inclusion into the CBSKY4 model. The YBSC includes stellar classification; however, there are far more than 87 different classes recognized by this catalog. Each star was assigned a spectral type in SKY system. To do the assignment, the spectral designation of the YBSC was evaluated. Essentially, a look-up table between YBSC spectral types and SKY spectral types was created.

3.1.4 Using the Catalogs Together

The Table 11 illustrates the distribution of SKY Spectral Types in the catalogs. Users can produce multi-spectral imagery that includes both bright infrared and bright visible stars. Known idiosyncrasies are that some stars are included in more than one catalog (those within approximately1 arcsec of each other) sometimes they have different spectral class assignments.

3.1.5 Future Development in Catalogs

The CBSKY4 code is flexible and extensible for the inclusion of additional star catalogs. Anticipated in the near future, is the 2MASS star catalog that will provide bright sources for the K band.

Table 11: The Number of Stars per Spectral Class for Each Catalog

SKY Template Number	Related Spectral Type	MSX Stars	IRAS Stars	YBSC Stars
1	B0,1 V	2	0	72
2	B2,3 V	1	0	238
3	B5 V	0	0	134
4	B8-A0 V	2	0	417
5	A2-5 V	1	0	1888
6	F0-5 V	2	0	760
7	F8 V	1	0	229
8	G0-2 V	0	0	175
9	G5 V	0	0	150
10	G8-K3 V	0	0	617
11	K4-5 V	0	0	114
12	M0-1 V	0	0	24
13	M2-3 V	0	0	14
14	M4-5 V	0	0	9
15	M late V	0	0	1
16	F8-G2 III	1	0	279
17	G5 III	1	0	109
18	G8 III	1	0	421
19	K0,1 III	12	0	700
20	K2,3 III	25	0	472
21	K4,5 III	19	0	329
22	M0 III	17	0	76
23	M1 III	10	2	94
24	M2 III	18	0	85
25	M3 III	50	1	65
26	M4 III	53	0	54
27	M5 III	80	0	20
28	M6 III	113	0	13
29	M7 III	101	3	16
30	YOUNG OB	3	0	954
31	A-G I-II	13	0	353
32	K-M2 I-II	37	0	196
33	M3-4 I-II	20	0	17
34	AGB M 01	3	0	0
35	AGB M 03	7	1	0
36	AGB M 05	74	6	0
37	AGB M 07	168	1	0
38	AGB M 09	247	1	0
39	AGB M 11	252	3	0
40	AGB M 13	176	0	0
41	AGB M 15	97	2	0
42	AGB M 17	47	0	0
43	AGB M 19	49	0	0
44	AGB M 21	19	0	0

SKY Template Number	Related Spectral Type	MSX Stars	IRAS Stars	YBSC Stars
45	AGB M 23	14	0	0
46	AGB M 25	16	0	0
47	AGB C 01	51	1	0
48	AGB C 03	74	0	0
49	AGB C 05	34	1	0
50	AGB C 07	17	1	0
51	AGB C 09	11	0	0
52	AGB C 11	8	1	0
53	AGB C 13	2	4	0
54	AGB C 15	2	3	0
55	AGB C 17	1	2	0
56	AGB C 19	0	0	0
57	AGB C 21	1	0	0
58	AGB C 23	1	0	0
59	AGB C 25	0	0	0
60	AGB CI 01	1	1	0
61	AGB CI 03	5	1	0
62	AGB CI 05	28	0	0
63	AGB CI 07	52	2	0
64	AGB CI 09	62	0	0
65	AGB CI 11	29	0	0
66	AGB CI 13	32	1	0
67	AGB CI 15	10	3	0
68	AGB CI 17	10	0	0
69	AGB CI 19	3	0	0
70	AGB CI 21	0	1	0
71	AGB CI 23	0	0	0
72	AGB CI 25	0	0	0
73	AGB CI 27	0	0	0
74	AGB CI 29	0	0	0
75	AGB CI 31	0	0	0
76	X 1E	0	2	0
77	X 1A	0	0	0
78	X 2	0	0	0
79	X 3	0	0	0
80	X 4	0	4	0
81	X 5	0	0	0
82	PN BLUE	50	0	0
83	PN RED	19	1	0
84	RN BLUE	15	0	0
85	RN RED	39	0	0
86	H II REG	187	0	0
87	T TAURI	7	0	0

4. Modeling Stars Using Statistical Distributions

4.1 Statistical Stars from the SKY4 Model

The SKY4 model provides a single line-of-sight statistical distribution of the number of point sources per unit angular area per magnitude interval for each of 87 spectral classes. (Cohen 1993, 1994). The SKY4 model is a detailed model for the infrared point source sky that comprises geometrically and physically realistic representations of the obvious galactic components. Features modeled include:

- The galactic disk
- The bulge
- The spheroid
- The spiral arms (including the 'local arm')
- The molecular ring, and
- The extragalactic sky (distant galaxies).

Galactic components are comprised of a statistical sampling of point sources, guided by the parallel Monte Carlo simulation of the Galaxy at 12 μm. Point sources are modeled by 87 different spectral types which are fully characterized by the:

- Scale height,
- Space density, and
- Absolute magnitude at BVJHK, 12 μm, and 25 μm.

The point sources along any line-of-sight are the sum of the point sources arising from each component (disk, bulge, spheroid, arms, molecular ring, and distant galaxies). SKY4 creates a histogram of star counts per magnitude bin for a given line-of-sight, bandpass, and limiting magnitude. The user may optionally modulate the star counts by inclusion of molecular clouds, absent regions, and extinction.

4.2 Molecular Clouds

Molecular clouds provided by SKY4 alone yield non-physical artifacts when images are created from SKY4 line-of-sight runs. Minor modifications to SKY4 provide the option of running the model with or without the molecular clouds. These modifications idealize molecular models as smooth elliptical shapes.

CBSKY4 models molecular clouds as an overlay to the point source image. Thus, clouds can be added to images including real stars, statistical stars, or the synthesis of real and statistical stars. In fact, the clouds can be modeled with neither statistical nor real stars. The clouds are statistically computed and placed as individual stars. When real stars are selected, and statistical stars are deselected, and clouds are selected, the clouds are statistical and not generated by placing individual stars read from catalogs.

The size and shape of each cloud is modeled using a Gaussian 2-D profile. In the CBSKY4 data files, there is a list of 52 molecular clouds in a separate data file called **cloud.dat**. The text file lists each cloud's center location in galactic coordinates and the angular extent along galactic latitude and longitude of a Gaussian 2-D profile. SKY4 runs yield star counts with and without the molecular clouds. CBSKY4 runs SKY4 with and without clouds for the clouds center, then redistributes the difference (the star counts due to the cloud) over a smooth 2-D Gaussian area. The 2-D Gaussian distribution of stellar counts is added on top of the existing image on a pixel by pixel basis. Table 12 gives galactic coordinates, size, and rotation angle for the molecular clouds.

Figure 5 shows a rectangular projection image in galactic coordinates centered on galactic longitude 356° and latitude 13.5°. The IRAS 12μm bandpass (CBSKY4 input 12UM) was used to generate the picture. To produce just the cloud both catalog and statistical stars were turned off. Only the cloud option produced the image of statistical stars in the vicinity of Rho Oph cloud are in the image. The input file for generating this picture is in Section 6.

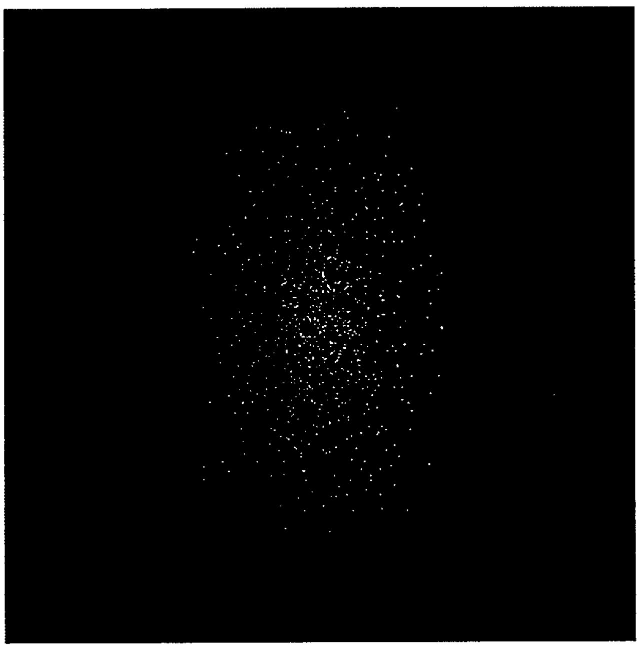


Figure 5: Cloud Rho Oph

4.3 Absent Regions

As with the molecular clouds, when images are generated from SKY4 line-of-sight calculations, severe artifacts result. The absent regions required a more intensive rework of SKY4. In the same spirit as the molecular clouds, the size and shape of each absent region is modeled using a Gaussian 2-D profile. In the CBSKY4 data files, there is a list of 10 absent regions in a separate data file called absent.dat. Since the stellar count in the absent regions decreased, the 2-D Gaussian code was integrated into the SKY4 model. The arms were also treated with 2-D Gaussian profiles. To have adequate spatial sampling of the absent regions, the triangle density of the triangle grid was increased around these regions. Table 13 gives galactic coordinates, size, and rotation angle for the absent regions.

Table 12: CBSKY4 Molecular Cloud Names, Locations and Sizes

Cloud Region Name	L0 Center Galactic Longitude (degrees)	Longitude Axis (degrees)	B0 Center Galactic Latitude (degrees)	Latitude Axis (degrees)	Ellipse Rotation Angle
LMC	279.65	9.3	-33.6	7.2	135.
SMC	302.75	5.5	-44.45	2.9	135.
Vul Rift	58.50	9.0	1.5	7.0	0.
Cyg Rift A	69.00	12.0	0.0	8.0	0.
Cyg Rift B	81.00	12.0	-3.0	14.0	0.
Cyg OB7	93.25	12.5	5.25	9.5	0.
Linnblad B	107.25	15.5	7.5	5.0	0.
Lindblad A	129.75	60.5	1.5	7.0	0.
TauAur Per	166.00	24.0	-15.5	19.0	0.
l=180a	180.00	40.0	7.5	5.0	0.
l=180b	180.00	40.0	3.5	3.0	0.
l=180c	180.00	40.0	1.25	1.5	0.
l=180d	180.00	40.0	0.0	1.0	0.
l=180e	180.00	40.0	-1.25	1.5	0.
l=180f	180.00	40.0	-7.5	5.0	0.
OriAB Mon	210.25	15.5	-13.5	15.0	0.
l=212a	212.50	25.0	-1.25	1.5	0.
l=212b	212.50	25.0	-3.5	3.0	0.
l=235d	235.00	20.0	-3.5	3.0	0.
l=235e	235.00	20.0	-7.5	5.0	0.
l=252a	252.5	15.0	-7.5	5.0	0.
l=252b	252.5	15.0	-3.5	3.0	0.
l=252c	252.5	15.0	-1.25	1.5	0.
l=267a	267.5	15.0	-7.5	5.0	0.
l=267b	267.5	15.0	-3.5	3.0	0.
l=267c	267.5	15.0	-1.25	1.5	0.
l=267d	267.5	15.0	0.0	1.0	0.
l=267e	267.5	15.0	1.25	1.5	0.
l=280a	280.00	10.0	-7.5	5.0	0.
l=280b	280.00	10.0	-3.5	3.0	0.
l=280c	280.00	10.0	-1.25	1.5	0.
l=280d	280.00	10.0	0.0	1.0	0.
l=280e	280.00	10.0	1.25	1.5	0.
l=280f	280.00	10.0	7.5	5.0	0.
l=290a	290.00	10.0	-7.5	5.0	0.
l=290b	290.00	10.0	-3.5	3.0	0.
l=290c	290.00	10.0	-1.25	1.5	0.
l=290d	290.00	10.0	0.0	1.0	0.
l=300a	300.00	10.0	-7.5	5.0	0.
l=300b	300.00	10.0	-3.5	3.0	0.
l=300c	300.00	10.0	-1.25	1.5	0.
l=300d	300.00	10.0	0.0	1.0	0.
l=300e	300.00	10.0	1.25	1.5	0.
l=300f	300.00	10.0	3.5	3.0	0.
l=300g	300.00	10.0	7.5	5.0	0.
l=310a	310.00	10.0	-7.5	5.0	0.
l=310b	310.00	10.0	-3.5	3.0	0.
l=310c	310.00	10.0	-1.25	1.5	0.
l=310d	310.00	10.0	0.0	1.0	0.
l=310e	310.00	10.0	1.25	1.5	0.
l=310f	310.00	10.0	6.0	8.0	0.
Rho Oph	356.00	12.0	13.5	21.0	0.

Table 13: CBSKY4 Absent Region Names, Locations and Sizes

Absent Region Name	L0 Center Galactic Longitude (degrees)	Longitude Axis (degrees)	B0 Center Galactic Latitude (degrees)	Latitude Axis (degrees)	Ellipse Rotation Angle
l=212a	215.00	20.0	3.5	3.0	0.
l=212b	215.00	20.0	1.25	1.5	0.
l=212c	215.00	20.0	0.0	1.0	0.
l=235a	232.50	15.0	1.25	1.5	0.
l=235b	232.50	15.0	0.0	1.0	0.
l=235c	232.50	15.0	-1.25	1.5	0.
l=252a	245.00	10.0	6.0	8.0	0.
l=252b	245.00	10.0	1.25	1.5	0.
l=252c	245.00	10.0	0.0	1.0	0.
l=267f	267.50	15.0	3.5	3.0	0.

5. The CBSKY4 Input File Format and Parameters

The CBSKY4 input file is hardwired to the name "Cbsky4.inp." This file should reside in the same directory as the code. The input files used to generate the examples in this document are provided in an Section 7.

The format follows the standard MS-Windows INI file format. The file is a text file and may be viewed and edited with a text editor. Input parameters are organized into sections, with a section label requiring a single text line. Following each section label, each input parameter is a single text line.

There are three kinds of lines in Cbsky4.inp

- Initialization variables, which are the functional lines, take the following format:
  `Initialization variable = value`

  Example:
  `image_center_longitude_degrees = 82.5000`

  Variables are read initially as string values and then interpreted by the code. Boolean variables can be set with "Yes", "No." A number of variables have a list of possible string values. Other variables allow numeric entry of integer or floating point values.

- Comments begin with a semicolon:
  `; comment`

  Example:
  `;from IRAS Sky Survey Atlas.`

  CBSKY4 ignores all comments.

- Section Headers are provided in brackets:
  `[$/Word]`

  Example:
  `[image]`

  Most headers provide a logical grouping of initialization variables, making it easier for the user to edit the file.

Example entry:

```
[image]
image_center_longitude_degrees = 82.5000 ;from IRAS Sky Survey Atlas.
```

The order of variables inside an initialization file does not matter at all; however, the header under which a variable is placed matters a great deal. If a variable is placed under the wrong section header, it may be ignored.

The CBSKY4 input file consists of these main section headers:

[path]	**[CBSKY4]**	**[image]**
[spectral]	**[convolution]**	**[positional]**
[time]		

The following pages describe each initialization variable in detail. They are organized by section heading, and then alphabetized for the initialization variables that are assigned to that heading.

[path] architecture

Summary:

Definition:	Sets the path delimiter defined by the operating system.
Valid:	DOS or UNIX
Default:	no default value; required input

Description:

The Architecture keyword establishes the path delimiter used for file specifications. Under DOS systems, which include all Microsoft Windows systems, the path delimiter is the "\" backward slash. Under UNIX systems, which include LINUX and IRIX systems, the path delimiter is the "/" forward slash.

[path] code_path

Summary:

Definition:	Full path to the subdirectory where the CBSKY4 image data are to be stored.
Valid:	The <pathname> path containing the CBSKY4 program. Following the default installation this is "\CBSD4\CBSD\CBSKY4".
Default:	no default value; required input

Description:

The Code_Path keyword specifies the location of the CBSKY4 program. The default installation Code_Path for MS-Windows systems is "\CBSD4\CBSD\CBSKY4". The final "\" is not needed. A code path in UNIX: "/CBSD4/CBSD/CBSKY4".

[path] log_output

Summary:

Definition:	Overrides the default <fileleaf> of all output files.
Valid:	<fileleaf> or <fileleaf>.log
Default:	no default value; not required in input file

Description:

The value of the Log_Output keyword defines the <fileleaf> of the output log text file. When this keyword is omitted from the input file, the filename follows the incremented "cbsky<nnn>.log" convention where <nnn> is a number from 1 to 999 incremented from the last cbsky<nnn>.log that resides in the output directory specified by the Path keyword. Thus, the first time you run CBSKY4 for a specific Path value, the output will be (the file extensions depend on whether FITS output or binary output was selected, and whether Catalog, Map,etc. are set):

<Path> cbsky001.map

<Path> cbsky001.sta

<Path> cbsky001.log

<Path> cbsky001.fit

etc.

The second run, will produce a set of files with a fileleaf of "cbsky002" and extensions of ".map", ".sta", ".fit", etc. Up to 999 runs can be produced for a given output Path.

If the Log_output keyword is set, then the file specifications will use the Path value, concatenated with the fileleaf of the Log_output value, concatenated with an extension defining the type of file. Image files have either a ".bin" or a ".fit" extension depending on whether the Output_format value is NONE or FITS.

Output Files	Description
<fileleaf>.bin	headerless binary image file (can be integer or floating point data values)
<fileleaf>.fit	binary image file in FITS file format
<fileleaf>.map	text file showing the difference between the SKY4 and CBSKY4 star counts meant for debugging purposes
<fileleaf>.sta	tabular text file of Log(magnitudes) in column 1 versus Log(star counts) in column 2
<fileleaf>.log	text file with success messages and details of processing and summary results
<fileleaf>.cat	tabular text file of star positions, types, magnitudes, fluxes, etc.

[path] path

Summary:

Definition:	Full path to the subdirectory where the CBSKY4 output data are to be stored.
Valid:	any <pathname> that currently exists on the system
Default:	no default value; required input

Description:

The value of the Path keyword is the path where all the output produced by CBSKY4 will be written. This includes the log files, the image binary files, the star catalogs, etc. It does not include a copy of the input file. Thus, the user may wish to copy the input file to that directory. CBSKY4 does not create this directory, and if it does not exist, the code will still run but may crash when writing the output image file.

If the Log_output keyword is set, then the file specifications will use the Path value, concatenated with the fileleaf of the Log_output value, concatenated with an extension defining the type of file. Image files have either a ".bin" or a ".fit" extension depending on whether the Output_format value is NONE or FITS.

Output Files	Description
<fileleaf>.bin	Headerless binary image file (can be integer or floating point data values)
<fileleaf>.fit	Binary image file in FITS file format
<fileleaf>.map	Text file showing the difference between the SKY4 and CBSKY4 star counts meant for debugging purposes
<fileleaf>.sta	Tabular text file of Log(magnitudes) in column 1 versus Log(star counts) in column 2
<fileleaf>.log	Text file with success messages and details of processing and summary results
<fileleaf>.cat	Tabular text file of star positions, types, magnitudes, fluxes, etc.

If no Log_output keyword is provided in the input file, the filenames are automatically incremented in the output directory. Thus, the first time you run CBSKY4 for a specific Path value, the output will be (the file extensions depend on whether fits output or binary output was selected, and whether Catalog, Map, etc. are set):

<Path> cbsky001.map

<Path> cbsky001.sta

<Path> cbsky001.log

<Path> cbsky001.fit

Etc.

The second run, will produce a set of files with a fileleaf of "cbsky002" and extensions of ".map", ".sta", ".fit", etc. Up to 999 runs can be produced for a given output Path.

[path] verbose

Summary:

Definition:	Sets the level of success and processing messages written to the log file.
Valid:	No Yes Loud
Default:	No

Description:

When the Verbose value is "NO", the log file does not include success messages and processing messages. When the Verbose value is "YES", the log file does include success messages and processing messages. When the Verbose value is "LOUD", the log file includes many messages that are useful for debugging.

[CBSKY4] catalog

Summary:

Definition:	Create an output catalog listing of stars included in the modeled scenario.
Valid:	yes no
Default:	no

Description:

When the catalog keyword is yes, CBSKY4 creates an output text file <fileleaf>.cat. This file lists the star locations and fluxes in the modeled scenario.

Each line in the output catalog describes a star in the image. The entries are Right Ascension (in degrees), Declination (in degrees), magnitude, spectral class (SKY's 1-87), source catalog (1=IRAS, 2=MSX, 3=Yale Bright Star Catalog) and flux (in Jy).

Notes:

Fainter stars have higher magnitude values. The higher the magnitude, the more stars included in the listing. A typical scene could result in output catalog files of over 100 Mbytes. Use the catalog_limit threshold to limit stars included in the catalog file, and hence the catalog file size. Use the magnitude_limit to threshold the stars included in the output, and hence reduce run-time.

Example:

For the Orion image presented earlier, Table 14 below lists the output of a catalog with a catalog limit of magnitude 3 for the V spectral band. The input file for generating this catalog listing is provided in the Section 7. Orion is famous for its hot, young OB stars (SKY Type 30).

Table 14: Sample out of the CBSKY4 stellar catalog file.

Right Ascension	Declination	Magnitude	Spectral Class	Catalog	Flux (Jansky)
68.262278	16.409710	-0.1738654	21	1	3.967E-09
72.424535	14.169373	2.7787196	22	1	2.615E-10
78.029306	-8.256815	-0.8680001	30	1	7.518E-09
82.319068	18.559455	2.4490589	32	1	3.542E-10
83.174611	-5.495305	-1.1767017	1	1	9.991E-09
83.257945	-5.295801	-2.1422117	1	1	2.431E-08
88.114508	7.400883	-1.4928668	32	1	1.337E-08
91.331987	-6.374648	1.1022027	85	1	1.225E-09
92.491647	18.003777	2.7210263	85	1	2.757E-10
92.963563	22.523927	2.8706929	25	1	2.402E-10
94.403635	-10.614598	0.7322221	84	1	1.722E-09
94.982804	22.540709	2.3545027	25	1	3.865E-10
68.262888	16.407713	0.8913612	32	3	1.487E-09
76.346241	-5.150663	2.7909519	5	3	2.585E-10
78.033512	-8.257995	0.1309763	30	3	2.996E-09
80.611888	6.305895	1.6817131	30	3	7.182E-10
82.359820	0.263732	2.2813688	30	3	4.134E-10
83.246491	-5.941264	2.8290252	30	3	2.496E-10
83.418656	-1.232277	1.7396323	30	3	6.809E-10
84.558543	-1.967674	2.0993074	30	3	4.889E-10
86.346074	-9.686005	2.1054589	30	3	4.861E-10
88.116216	7.399391	0.5001933	12	3	2.132E-09
94.984511	22.539618	2.8873885	25	3	2.366E-10

[CBSKY4] catalog_limit

Summary:

Definition:	The magnitude value of the faintest star to be included in the output catalog listing.
Valid:	floating point value [23.0, -10.0]
Default:	value of Magnitude_Limit

Description:

This sets the limit of the brightness of the point sources included in the output catalog. Typically, users want to threshold the stars written to the output catalog, because if all the stars were included, the file which has a text line per star, would be unwieldy. The Magnitude_Limit keyword sets the limit of star magnitude modeled. So, the brightness threshold of stars included in the output images and output tabulated statistical data are set by Magnitude_Limit. The Catalog_Limit imposes a second threshold on those stars for inclusion into the output catalog file. If the Catalog_Limit is set to a fainter (higher) value than the Magnitude_Limit, the Magnitude_Limit sets the value of the faintest stars included in the catalog.

Each line in the output catalog describes a star in the image. The entries are Right Ascension (in degrees), Declination (in degrees), magnitude, spectral class (SKY's 1-87), source catalog (1=IRAS, 2=MSX, 3=Yale Bright Star Catalog) and flux (in Jy).

Notes:

Fainter stars have higher magnitude values. The higher the number, the more stars included in the listing. A typical scene could result in output catalog files of over 100 Mbytes. Use this threshold to limit the file size.

Example:

Table 15 below shows the relation of total stars listed and file size for the Orion image presented earlier to the catalog limit from magnitude 1 to magnitude 15 for the V spectral band. The input file for generating the Orion image is listed in the Appendix.

Table 15: Expected file sizes based the catalog cutoff limiting magnitude parameter Catalog_limit.

Catalog Limit	Total Number of Catalog Stars Only	Real Stars Only Filesize (Bytes)	Total Number of Catalog Stars & Statistical Stars	Real Stars & Statistical Stars File Size (Bytes)
1	9	549	9	549
2	12	732	17	1037
3	23	1403	36	2196
4	42	2562	106	6466
5	100	6100	293	17873
6	267	16287	718	43798
7	469	28609	1368	83448
8	493	30073	2831	172691
9	501	30561	7983	486963
10	510	31110	21881	1334741

[CBSKY4] clouds

Summary:

Definition:	A flag to include or exclude modeling giant molecular cloud star populations (not the gas).
Valid:	YES NO
Default:	NO

Description:

Star counts are higher in regions of giant molecular clouds, because these are star forming regions. For this reason, Giant Molecular Cloud regions are mapped and modeled, that is, the higher stellar densities are accounted for, in the CBSKY4 model. The dust is not modeled in CBSKY4, however.

Notes:

Only works if using the pre-defined CBSD 12UM or 25UM bandpasses.

Example:

Figure 6 show the output produced by running the Section 7input file for the Rho Oph Cloud (cloud only - no statistical or real stars).

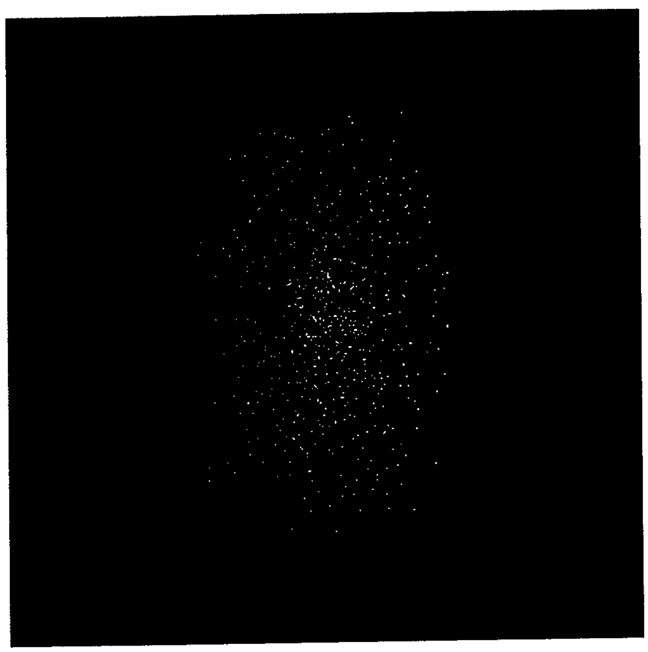


Figure 6: Rho Oph GMC as produced by CBSKY4.

[CBSKY4] count_statistics

Summary:

Definition:	Generate statistical output.
Valid:	Yes No
Default:	No

Description:

When selected, CBSKY4 will produce the SKY4 statistics information.

Notes:

This table is also included in the .log file.

Example:

With count_statistics = yes, the code produces the .sta statistics file. This is an 11 column table of tabulated statistics of the numbers of stars per magnitude bin.

Table 16: Count Statistics File Content.

Column	Description	Plot
1	a bin index	Plot Col. 2 vs. Col. 1 to create a histogram of star counts in each bin.
2	total number of stars in that bin (histogram)	
3	cumulative number of stars in that bin or in all brighter bins (cumulative histogram)	Plot Col. 3 vs. Col. 1 to create a cumulative histogram of star counts in each magnitude bin.
4	magnitude of the bin	Plot Col. 5 vs. Col. 4 for a cumulative Log(N)/Log(S) plot.
5	cumulative log(N) (log of the cumulative number of stars, that is, base 10 log of column 3 values)	
6	differential magnitude of the bin (values are shifted by half a bin size column 4 values)	Plot Col. 7 vs. Col. 6 for a differential (Log(N)/m)/Log(S) plot.
7	differential log(N) for magnitude bins (log of the number of stars per magnitude)	
8	log(flux) of the bin	Plot Col. 9 vs. Col. 8 for a cumulative Log(N)/Log(F) plot.
9	cumulative log(N) (log of the cumulative number of stars, that is, base 10 log of column 3 values, also equals column 5 values)	
10	log(flux) of the bin	Plot Col. 11 vs. Col. 10 for a differential (Log(N)/m)/Log(F) plot.
11	differential log(N) for flux bins	

[CBSKY4] elementsfile

Summary:

Definition:	Elementsfile specifies the name of a file which gives the element list (which connect nodes) of the triangles in the triangle map. The following node files have been defined:
Valid:	elem_va.dat elem_ia.dat elem_iah.dat
Default:	elements.dat
	Note: This file is not part of the distribution installation; however it is anticipated that the user will want to copy one of the three files above to be used as a default condition.

Description:

The **elementsfile** parameter specifies the name of a file which gives the element list (which connect nodes) of the triangles in the triangle map. These files reside in the \CBSD4\CBSD\sky4data directory created by the installation. The following node files are included in the distribution installation:

elem_va.dat	Visible,
elem_ia.dat	Infrared, low resolution.
elem_iah.dat	Infrared, high resolution.

The default is ***elements.dat****. This file does not exist, but it is expected that the user will copy one of the node files to specify a user defined default condition.*

Together, the elementsfile keyword and the nodesfile keyword define the triangular segmentation of the whole sky used for computing the statistical star counts per magnitude bin per spectral class values and used for placement of statistical stars in the image.

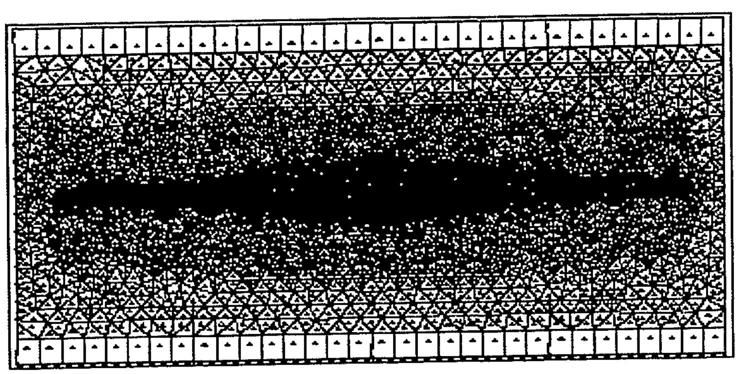


Figure 7: The spherical triangle map.

The entire sky represented by a set of spherical triangles.

Notes:

This option is only available when Statistical_Stars is set to YES.

The elementsfile and nodesfile are coupled, e.g., when the visible file elem_va.dat is selected, then the corresponding node_va.dat file must also be selected.

[CBSKY4] magnitude_limit

Summary:

Definition:	The magnitude value of the faintest star to be modeled.
Valid:	floating point value [23.0, -10.0]
Default:	11.0

Description:

This sets the lower magnitude limit, the faintest star, included in the output image and output statistical tabulations. The higher the number, the fainter the star modeled. Higher values yield higher accuracy since many faint stars in a single IFOV can combine to yield radiance higher than a single bright star. The higher accuracy has a cost in computation time. Thus the option for lower numbers is provided where only the brightest stars are considered significant sources of clutter and computation time is a consideration.

This value also sets the number of magnitude bins:

Number_of_Magnitude_Bins = 4x(Magnitude_Limit – Brightest_Magnitude)

Where the Brightest_Magnitude is –10.

Notes:

Fainter stars have higher magnitude values.

Catalog_Limit is the parameter for truncating the listing in the output catalog. Stars down to the limit set by magnitude_limit are included in the image; of those stars, only the ones brighter than catalog_limit are included in the catalog. Decoupling these limits allows the user to create high-fidelity images with a corresponding tabulated text file including information about the brightest objects.

Example:

Table 17 shows the relation of total stars included in the Orion image when varying the magnitude_limit value for the V spectral band. The input file for generating the Orion image is listed in the Section 7.

Table 17: Number of stars in an image centered on Orion with two different magnitude limits.

Catalog Limit	Number of Stars in Image
4	42
15	525

[CBSKY4] method

Summary:

Definition:	This flag sets the option for star placement.
Valid:	CENTER or VERTICES
Default:	CENTER

Description:

When Method is set to CENTER, for each spherical triangle a single SKY4 run is performed at the center of the triangle. This value is used uniformly within the triangle. This is the fastest option, and typically the recommended option for users.

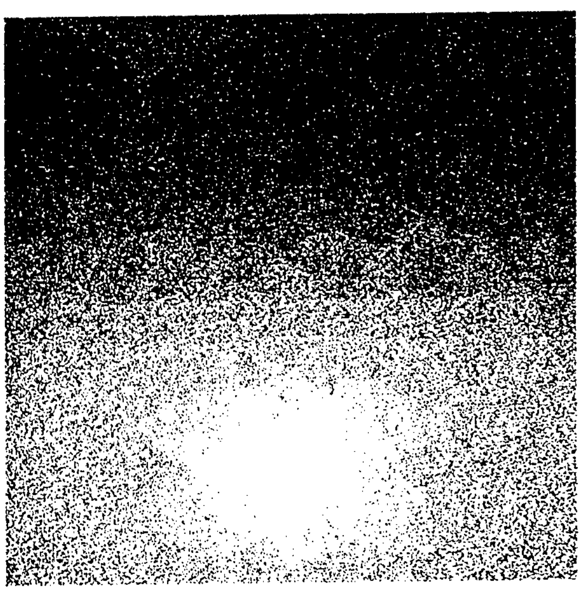
When Method is set to VERTICES, three SKY4 runs are used for each triangle, (one for each vertex of the triangle). The three values are averaged and used uniformly within the triangle. This is the slowest option. If users encounter scenes in which the triangular segmentation becomes apparent, the artifacts arising from statistical differences between adjacent triangles may be suppressed by selecting the VERTICES option.

Note:

This option is only available when Statistical_Stars is set to YES. This parameter does not affect the placement of catalog stars.

Example:

Figure 8 is an example of the Off-Plane Confused Region, and is a CBSD 12UM band image at B=3, L=0, IFOV = 0.02 degrees, run with CENTER (left) and VERTICES (right). The images were scaled to a maximum value of 1e-18. This stretch shows the triangle artifacts somewhat smoothed but not removed by using VERTICES.



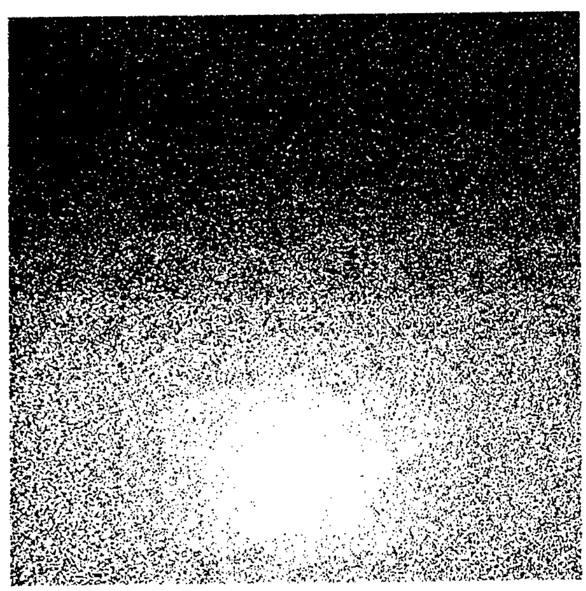


Figure 8: Off-plane confused region.

[CBSKY4] nodesfile

Summary:

Definition:	This specifies the name of a file that gives the node locations of the triangles in the triangle map.
Valid:	node_va.dat node_ia.dat node_iah.dat
Default:	nodes.dat
	Note: This file is note part of the distribution installation; however it is anticipated that the user will want to copy one of the three files above to be used as a default condition.

Description:

The **nodesfile** parameter specifies the name of a file which gives the node locations of the triangles in the triangle map. These files reside in the \CBSD4\CBSD\sky4data directory created by the installation. The following node files are included in the distribution installation:

node_va.dat	Visible,
node_ia.dat	Infrared, low resolution.
node_iah.dat	Infrared, high resolution.

The default is ***nodes.dat***. *This file does not exist, but it is expected that the user will copy one of the node files to specify a user defined default condition.*

When Method is set to VERTICES, three SKY4 runs are used for each triangle, one for each vertex of the triangle. The three values are averaged and used uniformly within the triangle. This is the slowest option. If users encounter scenes in which the triangular segmentation becomes apparent, the artifacts arising from statistical differences between adjacent triangles may be suppressed by selecting the VERTICES option.

Together, the elementsfile keyword and the nodesfile keyword define the triangular segmentation of the whole sky used for computing the statistical star counts per magnitude bin per spectral class values and used for placement of statistical stars in the image.

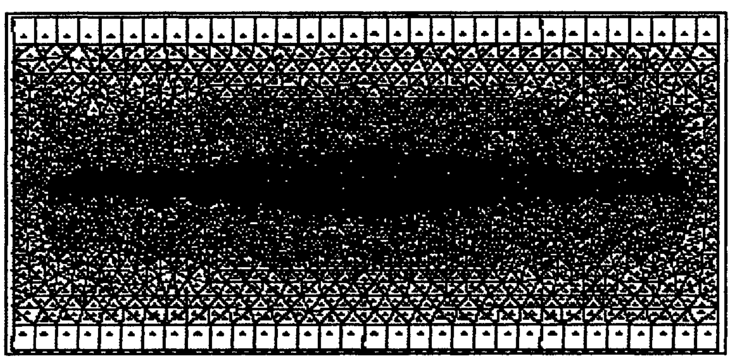


Figure 9: The spherical triangle map.
The entire sky represented by a set of spherical triangles.

Notes:

This option is only available when Statistical_Stars is set to YES.

The elementsfile and nodesfile are coupled; e.g., when the visible file elem_va.dat is selected, then the corresponding node_va.dat file must also be selected.

[CBSKY4] real_stars

Summary:

Definition:	Flag to select or unselect the option to include catalog stars.
Valid:	No Yes
Default:	Yes

Description:

When the Real_Stars keyword is set to NO, the real catalog stars are not included in the output image, catalog or other statistics. When the Real_Stars keyword is set to yes, catalog stars positions and magnitudes are read. The star's flux is computed based on the magnitude. The star is placed in the image. The star is added to tabulated statistics. If the catalog keyword is set to YES, then each star included in the image is also output to the catalog, provided that its magnitude is less than the catalog_limit value. Descriptions of catalogs of real stars are provided above.

Notes:

When real_stars are selected, multispectral overlays are possible.

[CBSKY4] seed

Summary:

Definition:	An integer value that specifies a starting random number seed.
Valid:	> 0
Default:	578

Description:

Random number generation is used extensively in the placement of statistical stars.

[CBSKY4] statistical_stars

Summary:

Definition:	Flag to select or unselect the option to include statistically placed stars.
Valid:	No Yes
Default:	Yes

Description:

When the Statistical_Stars keyword is set to NO, the stars generated by SKY4 are not included in the output image and output statistics and catalog files.

Notes:

When Statistical_Stars is set to NO, the following options are not available: Seed, Method

[image] image

Summary:

Definition:	Select or deselect the creation of an output image.
Valid:	NO YES
Default:	YES

Description:

When the image keyword is YES, then a binary image is created. The image format and type are defined by image_format and image_type. The units of each pixel's value is defined by units. The image dimensions are defined by the x_column_pixels and y_row_pixels values. The angular size of each pixel is defined by pixel_size. The center of the image is defined by the image_center_longitude_degrees (alternative: image_center_longitude_hours) and image_center_latitude values, and the coordinate system that defines these values is given by image_coordinate_system and equinox. The projection is given by image_projection. Along with the scene date and bandpass, these values define the image parameters.

Notes:

When image is selected (YES), then the image_center_longitude (or image_center_longitude_degrees) and the image_center_latitude keywords must also be included in the input file.

[image] image_center_latitude

Summary:

Definition:	Specifies the latitude or Declination of the center of the image.
Valid:	Any Latitude Format (see below)
Default:	No default value; Required Input

Description:

Astronomers use a variety of notations for referencing sky locations. To accommodate all users, CBSD has a built-in intelligent parser that accepts all common notations. The format is a spaced delimited set of integer and decimal values. The field length of any decimal value can be any floating point value.

Formats for the image_center_latitude parameter

Latitude Formats	Description
±DD.DDDD	The ***image_center_latitude*** parameter specifies the latitude center of the image in decimal degrees. For the equatorial system, ***image_center_latitude*** is Declination. The range of values is from -90.0° to +90.0°. <u>*No default.*</u>
±D D MM.MM	Optionally, the ***image_center_latitude*** parameter can specify the latitude center of the image in integer degrees and decimal minutes. The range of values is from -90° 0.0' to +90° 0.0'.
±D D MM SS.SS	Optionally, the ***image_center_latitude*** parameter can specify the latitude center of the image in integer degrees, integer minutes, and decimal seconds. The range of values is from -90° 0' 0.0" to +90° 0' 0.0".

Notes:

The image_center_latitude value is interpreted according to the values of image_coordinate_system and reference_frame (equinox). When both are specified, the code uses the first one found.

[image] image_center_longitude_hours OR image_center_longitude_degrees

Summary:

Definition:	Specifies the longitude or Right Ascension of the center of the image.
Valid:	Any Longitude Format (see below)
Default:	no default value; required input

Description:

Astronomers use a variety of notations for referencing sky locations. To accommodate all users, CBSD has a built-in intelligent parser that accepts all common notations. The format is a spaced delimited set of integer and decimal values. The field length of any decimal value can be any floating point value.

Formats for the image_center_longitude_hours parameter

Longitude Formats	Description
HH.HHHH	The ***image_center_longitude_hours*** parameter specifies the longitude center of the image in decimal hours. For the equatorial system, ***image_center_longitude*** is Right Ascension. The range of values is from 0.0^h to 24.0^h. *No default.*
HH MM.MM	Optionally, the ***image_center_longitude_hours*** parameter can specify the longitude center of the image in integer hours and decimal minutes. The range of values is from $0^h\ 0.0^m$ to $24^h\ 0.0^m$.
HH MM SS.SS	Optionally, the ***image_center_longitude_hours*** parameter can specify the longitude center of the image in integer hours, integer minutes, and decimal seconds. The range of values is from $0^h\ 0^m\ 0.0^s$ to $24^h\ 0^m\ 0.0^s$.

Formats for the image_center_longitude_degrees parameter

Longitude Formats	Description
DDD.DDDD	The ***image_center_longitude_degrees*** parameter specifies the longitude center of the image in decimal degrees. For the equatorial system, ***image_center_longitude*** is Right Ascension which is formally measured in hours. Degrees are obtained by multiplying the Right Ascension, in hours, by 15. The range of values is from 0.0° to 360.0°. *No default.*
DDD MM.MM	Optionally, the ***image_center_longitude_degrees*** parameter can specify the longitude center of the image in integer degrees and decimal minutes. The range of values is from 0° 0.0' to 360° 0.0'.
DDD MM SS.SS	Optionally, the ***image_center_longitude_degrees*** parameter can specify the longitude center of the image in integer degrees, integer minutes, and decimal seconds. The range of values is from 0° 0' 0.0" to 360° 0' 0.0".

Notes:

The image_center_longitude_<hours/degrees> value is interpreted according to the values of image_coordinate_system and equinox. When both are specified, the code uses the first one found.

[image] image_coordinate_system

Summary:

Definition:	Defines the coordinate system used.
Valid:	Galactic Equatorial Ecliptic
Default:	Galactic

Description:

When the image_coordinate_system value is galactic, the galactic coordinates (L,B) are defined for B1950.0. When the value is equatorial, the equatorial Right Ascension and Declination (RA/Dec) values are referenced to the value of equinox. When the value is ecliptic, the ecliptic latitude and longitude (L,B) are used and referenced to the value of equinox.

Notes:

Example:

```
[Image]
image_center_longitude_degrees = 0.000000000
image_center_latitude = 0.000000000

[Positional]
Reference_Frame = B1950
coordinate_system = galactic
```

is equivalent to:

```
[Image]
image_center_longitude_degrees = -94.3892
image_center_latitude = -28.9168

[Positional]
Reference_Frame = B1950
coordinate_system = galactic
```

is equivalent to:

```
[Image]
image_center_longitude_hours = 17.760323
image_center_latitude = -28.936177

[Positional]
Reference_Frame = J2000
coordinate_system = galactic
```

[image] image_projection

Summary:

Definition:	Map projection used when creating the image.
Valid:	Rectangular Gnomonic Mollweide
Default:	Gnomonic

Description:

An image projection is the mapping of a 3D space or curved sheet onto a 2D flat sheet. Like map projections for the earth (Universal Mercator, Polar Stereographic, etc.), the celestial sphere can be projected onto an image in a variety of ways.

Descriptions of the different options:

Rectangular	The *Rectangular* projection is the familiar Mercator type of projection with parallel lines of latitude and parallel lines of longitude. Maps produced by CBSKY using the *Rectangular* projection do not "wrap" at the poles. This is not the case at 0^h and 24^h were "wrapping" is allowed.
Gnomonic	The *Gnomonic* projection is the projection of a sphere onto a plane from a tangent point; in other words, as a camera would see it. *Default.*
Mollweide	The *Mollweide* projection is an equal-area sinusoidal projection with the lines of latitude all parallel. The *Mollweide* projection is only used as an all sky projection. It is recommended that the ratio of ***x_column_pixels*** to ***y_row_pixels*** be 2:1 for a more pleasing image.

[image] image_type

Summary:

Definition:	Size of a pixel.
Valid:	BYTE 4-BYTE-REAL
Default:	4-BYTE-REAL

Description:

When BYTE is selected, the output image is stored as an 8-bit, unformatted image.

When 4-BYTE-REAL is selected, the output image is stored as a 4-byte, unformatted, floating point number. Floating point data are stored in the native format of the computer used to generate images.

Notes:

When transferring the image to a different computer the user must be aware of the need to perform byte swapping if 4-BYTE-REAL data is stored.

The FITS image format stores the gains and offsets needed to convert the values to decimal units of flux.

Collectively, the pixel_size, image_type, and units define the angular extent, the data representation and the units of flux of each pixel in the output image.

[image] output_format

Summary:

Definition:	Defines the file format of the output image.
Valid:	NONE FITS
Default:	FITS

Description:

A value of NONE produces an unformatted image, either byte or word as specified by image_type, with no header.

The FITS format is standard FITS specified by NASA GSFC FITS Committee. Reference: "Implementation of the Flexible Image Transport System (FITS)", NOST report 100-03b.

Description:

Search the Web for FITS readers. Code libraries are available in C, FORTRAN, IDL and other languages.

[image] pixel_size

Summary:

Definition:	The angular extent of a pixel.
Valid:	> 0.0 degrees (the upper limit depends upon the image projection selected and the array size)
Default:	0.5 degrees

Description:

The angular size of each pixel in degrees per pixel. Each pixel is taken to be square. As the image is being created, each star is assigned to a pixel and the total radiance from that point source fills the pixel. When a convolution is specified, the sum of all contributions to that pixel is treated as a single flux at the center of that pixel. Thus all convolved output is still centered on a pixel.

Notes:

If no image is generated (image=NO), then this value is ignored.

[image] units

Summary:

Definition:	Define the flux units of an image pixel.		
Valid:	W/CM2/MICRON/SR W/CM2/MICRON	W/CM2/SR JY	W/CM2 JY/SR
Default:	W/CM2		

Description:

The units keyword defines the flux units of an image pixel are given in Table 18.

Table 18: List of CBSD allowed input units parameters and description.

Named Unit	Description
W/CM2/MICRON/SR	Spectral Irradiance in units of W/cm^2/sr/μm.
W/CM2/SR	Irradiance in units of W/cm^2/sr.
W/CM2	Flux density in units of W/cm^2.
W/CM2/MICRON	Spectral flux density in units of W/cm^2/μm.
JY	Irradiance in units of Jy.
JY/SR	Spectral Irradiance in units of Jy/sr.

Notes:

This unit applies only to the flux value of a pixel in the image. It does not apply to flux values reported in the output star catalog or other flux values in the statistics and log files.

[image] x_column_pixels

Summary:

Definition:	The horizontal image size in pixels.
Valid:	Integer value from 1 to 1024
Default:	256

Description:

Together with y_row_pixels, this parameter defines the array size of the output image. The pixel_size and array size define the FOV.

Notes:

This parameter is only used when image is set to yes. If the simulation fails because the user defined image size exceeds the limits, change the following line in image.h:

```
parameter (xsize=1024,ysize=1024)
```

and recompile the code.

[image] y_row_pixels

Summary:

Definition:	The vertical image size in pixels.
Valid:	Integer value from 1 to 1024
Default:	256

Description:

Together with x_column_pixels, this parameter defines the array size of the output image. The pixel_size and array size define the FOV.

Notes:

This parameter is only used when image is set to yes. If the simulation fails because the user defined image size exceeds the limits, change the following line in image.h:

```
parameter (xsize=1024,ysize=1024)
```

and recompile the code.

[convolution] convolution

Summary:

Definition:	Specify whether or not the output image is convolved, and the convolution filter
Valid:	NO GAUSSIAN CIRCULAR
Default:	NO

Description:

Convolution of the output image is optional. Together with point_spread_function this parameter allows the user to specify a convolution filter.

Notes:

Surface plots of a star in the output image, convolved using the GAUSSIAN filter (left) and the CIRCULAR filter (right). The CIRCULAR filter has some sharp artifacts (Figure 10). GAUSSIAN is recommended.

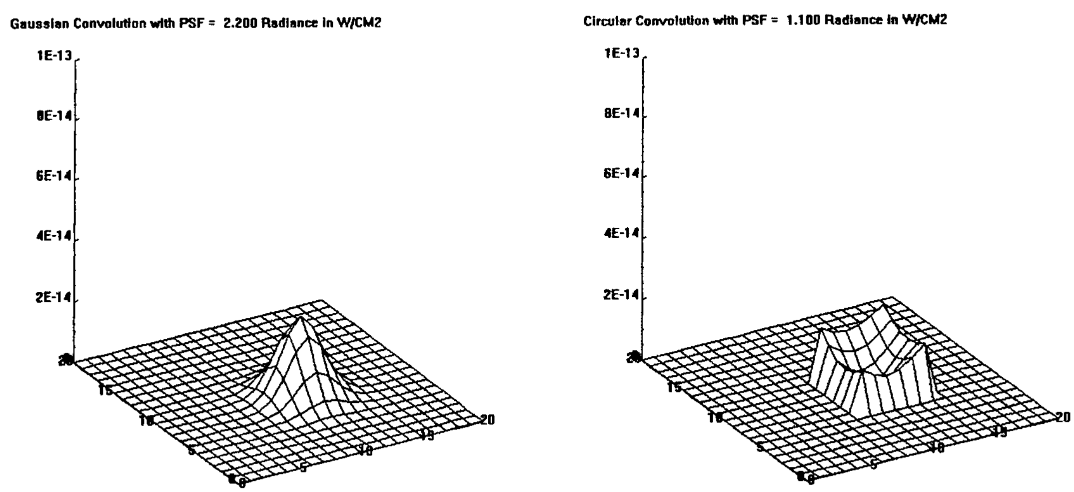


Figure 10: Point Spread function results.

[convolution] point_spread_function

Summary:

Definition:	Specify the point spread function half-width in pixels.
Valid:	floating point value > 0.0
Default:	no default value; required if convolution is selected

Description:

Convolution of the output image is optional. Together with convolution this parameter allows the user to specify a convolution filter.

Notes:

Only valid if convolution is set to GAUSSIAN or CIRCULAR.

[spectral] band_center

Summary:

Definition:	Defines the center of the spectral limits in μm.
Valid:	Any floating point value from 2 to 30 μm.
Default:	no default value; required input unless using start_wavelength

Description:

The value of the band_center is interpreted as the center of the bandpass in μm, the value of band_width is interpreted as the width of the bandpass.

Notes:

The smallest interval of integration in CBSKY4 is 0.1 μm. The companion codes CBZODY can integrate a 0.01 or 0.1 μm interval, and CBAMP can integrate any spectral interval, provided that machine-dependent underflows do not occur.

Also specify band_center.

The start_wavelength and end_wavelength should not be specified if using band_center and band_width.

Example:

[spectral]

band_center = 11.0

band_width = 2.0

specifies a square filter from 10 to 12 μm.

[spectral] band_width

Summary:

Definition:	Defines the width of the spectral limits in µm.
Valid:	> 0.1 µm
Default:	no default value; required input unless using start_wavelength

Description:

The value of the band_center is interpreted as the center of the bandpass in µm, the value of band_width is interpreted as the width of the bandpass.

Notes:

The smallest interval of integration in CBSKY4 is 0.1 µm. The companion codes CBZODY can integrate a 0.01 or 0.1 µm interval, and CBAMP can integrate any spectral interval, provided that machine-dependent underflows do not occur.

Also specify band_width.

The start_wavelength and end_wavelength should not be specified if using band_center and band_width.

Example:

[spectral]

band_center = 11.0

band_width = 2.0

specifies a square filter from 10 to 12 µm.

[spectral] end_wavelength

Summary:

Definition:	Defines the upper spectral limit in μm.
Valid:	Any floating point value from 2 to 30 μm that is greater than the start_wavelength
Default:	no default value; required input unless start_wavelength is a pre-defined bandpass name.

Description:

The value of the end_wavelength is interpreted as the upper limit of the band-pass in μm.

Notes:

The smallest interval of integration in CBSKY4 is 0.1 μm. The companion codes, CBZODY, can integrate a 0.01 or 0.1 μm interval; CBAMP can integrate any spectral interval, provided that machine-dependent underflows do not occur.

The end_wavelength should be larger than the start_wavelength.

If the start_wavelength is a name of a pre-defined bandpass, the end_wavelength is ignored.

The band_center and band_width should not be specified if using start_wavelength and end_wavelength

Example:

[spectral]

start_wavelength = 10.0

end_wavelength = 12.0

specifies a square filter from 10 to 12 μm.

[spectral] start_wavelength

Summary:

Definition:	Defines EITHER the lower spectral limit in µm OR the predefined named bandpass.
Valid:	Any floating point value from 2 to 30 µm.
	OR <filespec> OR Any named bandpass:
	1400A, 1565A, 1660A, B, V, J, H, K, 2.4UM, 12UM, or 25UM
Default:	no default value; required unless band_center and band_width are specified

Description:

The CBSKY4 program reads the start_wavelength value as a string. If the string is a spectral filter file, then that file is used as the bandpass and filter. See the description for the spectral_filter_file keyword for more information. If the string value corresponds to a name of a pre-defined bandpass and filter, that band is used, and the value of end_wavelength is ignored. Otherwise, the value of the start_wavelength is interpreted as the lower limit of the band-pass in µm. Table 19 gives a listing of the CBSD named bands.

Table 19: The Named Bands.

CBSD input bands	Effective Wavelength	Standard
1400A	1400Å	1400Å ultraviolet channel Apollo 16 "S201"
1565A	1565Å	TD1 1565Å ultraviolet channel
1660A	1660Å	FAUST 1660Å ultraviolet channel
B	0.44µm	standard B photometric band (0.44µm)
V	0.55µm	standard V photometric band (0.55µm)
J	1.25µm	standard J photometric band (1.25µm)
H	1.65µm	standard H photometric band (1.65µm)
K	2.22µm	standard K photometric band (2.22µm)
2.4UM	2.4µm	COBE 2.4µm bandpass
12UM	12µm	IRAS 12µm bandpass
25UM	25µm	IRAS 25µm bandpass

Notes:

The smallest interval of integration in CBSKY4 is 0.1 µm. The companion codes CBZODY can integrate a 0.01 or 0.1 µm interval; CBAMP can integrate any spectral interval, provided that machine-dependent underflows do not occur.

The end_wavelength should be larger than the start_wavelength.

CBSKY4 has wavelength coverage of 0.2µm to 30µm; however, wavelengths shorter than 2µm are not continuous. For these regions, the named bands must be used.

The band_center and band_width should not be specified if using start_wavelength.

Example:

All are valid inputs:

start_wavelength = \CBSD4\CBSD\rsr\IRAS3.dat

start_wavelength = 12UM

start_wavelength =3.45

[time] interval_days_hours_minutes_seconds

Summary:

Definition:	Defines the number time interval length in a time series.
Valid:	"DD HH MM SS" format
Default:	no default value; require input

Description:

The time interval between observation times of successive simulations in a time series.

Notes:

Use with either the observation_julian_start and observation_julian_stop pair or with the observation_date_start/observation_time_start and observation_date_stop/observation_time_stop time limits.

Example:

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

number_of_time_periods = 3

or

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

interval_days_hours_minutes_seconds = 0 0 10 0

[time] number_of_time_periods

Summary:

Definition:	Defines the number of frames in a time series.
Valid:	integer > 0
Default:	no default value

Description:

The observation_date keyword can be used to set the day, month and year to be modeled. This keyword supersedes all other time inputs that might be included in the input file.

In the "DD MM YYYY" format, the Gregorian calendar day is entered. For the DD part of the string, enter the day number (valid values are from 1 to 31). For the MM part of the string, enter the month number (valid values are from 1 to 12 with 1 being January and 12 being December). For the YYYY part of the string, enter the year.

Notes:

Use with either the observation_julian_start and observation_julian_stop pair or with the observation_date_start/observation_time_start and observation_date_stop/observation_time_stop time limits.

Example:

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

number_of_time_periods = 3

or

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

interval_days_hours_minutes_seconds = 0 0 10 0

[time] observation_date

Summary:

Definition:	Defines the day, month, and year to be modeled.
Valid:	"DD MM YYYY" format
Default:	no default value

Description:

The observation_date keyword can be used to set the day, month and year to be modeled. This keyword supersedes all other time inputs that might be included in the input file.

In the "DD MM YYYY" format, the Gregorian calendar day is entered. For the DD part of the string, enter the day number (valid values are from 1 to 31). For the MM part of the string, enter the month number (valid values are from 1 to 12 with 1 being January and 12 being December). For the YYYY part of the string, enter the year.

Notes:

When observation_date is used, observation_time should also be used.

Typically, the date and time to be modeled is read but irrelevant for CBSKY4, however, it may be used in the future for example to allow for the specification of observation position as a function of time in an orbit or along a trajectory.

Example:

[time]

observation_date = 2 2 2001

observation_time = 0 30 0

[time] observation_date_start

Summary:

Definition:	Defines the starting day, month, and year to be modeled.
Valid:	"DD MM YYYY" format
Default:	no default value

Description:

The observation_date_start keyword can be used to set the day, month and year of the first of a time sequence of runs to be modeled.

In the "DD MM YYYY" format, the Gregorian calendar day is entered. For the DD part of the string, enter the day number (valid values are from 1 to 31). For the MM part of the string, enter the month number (valid values are from 1 to 12 with 1 being January and 12 being December). For the YYYY part of the string, enter the year.

Notes:

If the observation_date_start is specified, then the observation_date_stop, observation_time_start, and observation_time_stop, must also be included.

Observation_date_start can't be used with observation_julian_stop to define a time interval.

Typically, the date and time to be modeled is read but irrelevant for CBSKY4, however, it may be used in the future for example to allow for the specification of observation position as a function of time in an orbit or along a trajectory.

In CBSKY4, only one model simulation is performed, since time is irrelevant.

Example:

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

number_of_time_periods = 3

or

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

interval_days_hours_minutes_seconds = 0 0 10 0

[time] observation_date_stop

Summary:

Definition:	Defines the final day, month, and year to be modeled.
Valid:	"DD MM YYYY" format
Default:	no default value

Description:

The observation_date_stop keyword can be used to set the day, month and year of the last of a time sequence of runs to be modeled.

In the "DD MM YYYY" format, the Gregorian calendar day is entered. For the DD part of the string, enter the day number (valid values are from 1 to 31). For the MM part of the string, enter the month number (valid values are from 1 to 12 with 1 being January and 12 being December). For the YYYY part of the string, enter the year.

Notes:

If the observation_date_start is specified, then the observation_date_stop, observation_time_start, and observation_time_stop, must also be included.

Observation_date_start can't be used with observation_julian_stop to define a time interval.

Typically, the date and time to be modeled is read but irrelevant for CBSKY4, however, it may be used in the future for example to allow for the specification of observation position as a function of time in an orbit or along a trajectory.

In CBSKY4, only one model simulation is performed, since time is irrelevant.

Example:

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

number_of_time_periods = 3

or

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

interval_days_hours_minutes_seconds = 0 0 10 0

[time] observation_julian

Summary:

Definition:	Defines the time, day, month, and year to be modeled.
Valid:	"JJJJJJJ.JJJJJJ" format
Default:	no default value

Description:

The observation_julian keyword can be used to set the day, month, year and time to be modeled.

In the "JJJJJJJ.JJJJJJ" format, the Julian Date is entered. The decimal portion defines the fractional days, and thus the time.

Julian Day is a continuous count of days and fractional days since the beginning of the year –4712 (1 January 4713 BC) at Greenwich noon. By tradition, the Julian Day begins at Greenwich mean noon (12 hour Universal Time). Thus, January 1, 2000 at UT 0:00 is JD 2451544.5 and January 1, 2000 at UT 12:00 is JD 2451545.0

Notes:

When observation_julian is used, observation_time is not used.

Typically, the date and time to be modeled is read but irrelevant for CBSKY4, however, it may be used in the future for example to allow for the specification of observation position as a function of time in an orbit or along a trajectory.

Example:

```
[time]
observation_julian = 2451576.500000
```

[time] observation_julian_start

Summary:

Definition:	Defines the starting time, day, month, and year to be modeled.
Valid:	"JJJJJJJ.JJJJJJ" format
Default:	no default value

Description:

The observation_julian_stop keyword can be used to set the day, month, year and time of the last of a time sequence of runs to be modeled.

In the "JJJJJJJ.JJJJJJ" format, the Julian Date is entered. The decimal portion defines the fractional days, and thus the time.

Julian Day is a continuous count of days and fractional days since the beginning of the year –4712 (1 January 4713 BC) at Greenwich noon. By tradition, the Julian Day begins at Greenwich mean noon (12 hour Universal Time). Thus, January 1, 2000 at UT 0:00 is JD 2451544.5 and January 1, 2000 at UT 12:00 is JD 2451545.0

Notes:

When observation_julian is used, observation_time is not used.

Typically, the date and time to be modeled is read but irrelevant for CBSKY4, however, it may be used in the future for example to allow for the specification of observation position as a function of time in an orbit or along a trajectory.

Example:

[time]

observation_julian_start = 2451576.500000

observation_julian_stop = 2451576.52803

number_of_time_periods = 3

or

[time]

observation_julian_start = 2451576.500000

observation_julian_stop = 2451576.52803

interval_days_hours_minutes_seconds = 0 0 10 0

[time] observation_julian_stop

Summary:

Definition:	Defines the final day, month, and year to be modeled.
Valid:	"DD MM YYYY" format
Default:	no default value

Description:

The observation_date_stop keyword can be used to set the day, month and year of the last of a time sequence of runs to be modeled.

In the "DD MM YYYY" format, the Gregorian calendar day is entered. For the DD part of the string, enter the day number, valid values are from 1 to 31. For the MM part of the string, enter the month number, valid values are from 1 to 12 with 1 being January and 12 being December. For the YYYY part of the string, enter the year.

Notes:

Typically, the date and time to be modeled is read but irrelevant for CBSKY4, however, it may be used in the future for example to allow for the specification of observation position as a function of time in an orbit or along a trajectory.

If the observation_date_start is specified, then the observation_date_stop, observation_time_start, and observation_time_stop, must also be included.

Observation_date_start can't be used with observation_julian_stop to define a time interval.

In CBSKY4, only one model simulation is performed, since time is irrelevant.

Example:

[time]

observation_julian_start = 2451576.500000

observation_julian_stop = 2451576.52803

number_of_time_periods = 3

or

[time]

observation_julian_start = 2451576.500000

observation_julian_stop = 2451576.52803

interval_days_hours_minutes_seconds = 0 0 10 0

[time] observation_time

Summary:

Definition:	Defines the time to be modeled.
Valid:	"HH MM SS.S" format
Default:	no default value

Description:

The observation_time keyword can be used to set the time of day to be modeled.

Notes:

When observation_time is used, observation_date should also be used, but not observation_julian.

Example:

[time]

observation_date = 2 2 2001

observation_time = 0 30 0

[time] observation_time_start

Summary:

Definition:	Defines the start time of a time series simulation.
Valid:	"HH MM SS.S" format
Default:	no default value

Description:

The observation_time keyword can be used to set the time of day to be modeled, when a time series is being modeled.

Notes:

Also need observation_time_stop and either interval_days_hours_minutes_seconds or number_of_time_periods.

Example:

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

number_of_time_periods = 3

or

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

interval_days_hours_minutes_seconds = 0 0 10 0

[time] observation_time_stop

Summary:

Definition:	Defines the final time of a time series simulation.
Valid:	"HH MM SS.S" format
Default:	no default value

Description:

The observation_stop_time keyword can be used to set the time of day to be modeled, when a time series is being modeled.

Notes:

Also need observation_time_start and either interval_days_hours_minutes_seconds or number_of_time_periods.

Example:

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

number_of_time_periods = 3

or

[time]

observation_date_start = 2 2 2001

observation_time_start = 0 30 0

observation_date_stop = 2 2 2001

observation_time_stop = 1 0 0

interval_days_hours_minutes_seconds = 0 0 10 0

[time] time_stamp

Summary:

Definition:	Defines the unit of time of the input observation times.
Valid:	UTC UT1 TDT
Default:	UTC

Description:

The time_stamp keyword defines the unit of time of the input time values.

Time Unit	Meaning
UTC	Inputs are in Coordinated Universal Time
UT1	Inputs are in Universal Mean Solar Time
TDT	Inputs are in Terrestrial Dynamical Time

The Coordinated Universal Time (UTC) is the time scale available from broadcast time signals and is maintained to within +/- 0.90 seconds of Universal (Mean Solar) Time by the introduction of one second steps (leap seconds). UTC is a time scale based on international atomic time (TAI) measured from the vibration of Cesium atoms. UTC and TAI differ by an integral number of seconds. UTC is the basis for most legal time systems. The Universal (Mean Solar) Time (UT1) is a measure of time based conceptually on the diurnal motion of the fictitious mean sun, under the assumption that the Earth's rate of rotation is constant.

Coordinated Universal Time (UTC) ~ Universal (Mean Solar) Time

Coordinated Universal Time (UTC) = Universal (Mean Solar) Time +/- 0.90 seconds and

Universal (Mean Solar) Time = Coordinated Universal Time (UTC) +/- 0.90 seconds.

The Terrestrial Dynamical Time (TDT) is the independent argument for apparent geocentric ephemeredes:

TDT = TAI + 32.184 seconds.

Notes:

The date and time to be modeled is read but irrelevant for CBSKY4, however, it may be used in the future for example to allow for the specification of observation position as a function of time in an orbit or along a trajectory.

[positional] coordinate_system

Summary:

Definition:	Define the location of the equinox.
Valid:	Galactic, Equatorial, Ecliptic, User, Sun Centered Ecliptic, Horizon
Default:	J2000

Description:

The locations of objects in the sky are defined by celestial coordinates analogous to the terrestrial latitude/longitude system. Astronomers have defined many systems, suitable for different purposes. The systems, typically centered on the Earth, the observer, or the Sun, are spherical coordinate systems. Each system is defined by a *fundamental circle* and a *fixed point on it.* The fundamental circle lies in the x-y plane, and it is in this plane that the longitude angle is measured referenced to some fixed point. The latitude is the measure of elevation above/below the fundamental circle.

System	Description	Coordinates
Galactic	An earth-centered spherical coordinate system, with the x-y plane in the plane of the galaxy, and the x-axis pointing to the assumed center of the galaxy.	Longitude, l, is the angle measured in the plane of the galaxy from the center of the galaxy. Latitude, b, is the elevation angle above or below the plane of the galaxy. Galactic coordinates are referenced only to the epoch B1950.
Ecliptic	An earth-centered spherical coordinate system, with the x-y plane in the plane of the ecliptic (Earth's orbit around the Sun), and the x-axis pointing to the equinox point.	Longitude, λ, is the angle measured in the plane of the ecliptic from the Vernal equinox (Aries point). Latitude, β, is the elevation angle above or below the plane of the ecliptic.
Equatorial	An earth-centered spherical coordinate system, with the x-y plane in the plane of the Earth's equator, and the x-axis pointing to the equinox point.	Longitude, more commonly called the Right Ascension, RA (α), is measured in the plane of the equator from the Vernal equinox (Aries point). By tradition, Right Ascension is reported in hours rather than degrees. Latitude, more commonly called Declination, Dec (δ), is the elevation angle above or below the equator.
Sun Centered Ecliptic	A Sun-centered spherical coordinate system, with the x-y plane in the plane of the ecliptic (Earth's orbit around the Sun), and the x-axis pointing to the Sun.	Longitude, λ, is the angle measured in the plane of the ecliptic from the position of the Sun. Latitude, β, is the elevation angle above or below the plane of the ecliptic.
Horizon	An earth-surface-observer-based spherical coordinate system with the horizon as the x-y plane and the z-axis pointing along the observer zenith.	The azimuth is the angular distance in the horizon plane measured in degrees clockwise from due North. The altitude angle is the elevation above the horizon plane, objects below the horizon have a negative altitude. Alternatively, the zenith angle is the angle measure from the zenith towards the horizon.

Notes:

Typically, the radial part of the spherical system is treated as an infinite value; however, new techniques have provided distance estimates to and between many celestial objects. Where distance measures are provided, they may be reported in AU, km, parsecs, or some other astronomical unit of length.

[positional] observer_altitude

Summary:

Definition:	The height above the Earth's surface, in meters, of an observer as defined by the Earth's reference geoid of 1976.
Valid:	floating point value > 0.0
Default:	no default value; required input

Description:

The observer_altitude is the height above the Earth's surface, in meters, of an observer as defined by the Earth's reference geoid of 1976.

Notes:

For CBSKY4, since the distances to the stellar objects are so great, for most applications the observer altitude is irrelevant.

[positional] observer_geographic_latitude

Summary:

Definition:	Geographic latitude of observer in degrees +North.
Valid:	Floating point value +/- 90 degrees.
Default:	no default value; required input

Description:

The location of the observer.

Notes:

Obscuration by earth is not modeled. In CBSKY4, this input is only used for time conversions.

[positional] observer_geographic_longitude

Summary:

Definition:	Geographic longitude of observer in degrees +West.
Valid:	Floating point value +/- 360 degrees.
Default:	no default value; required input

Description:

The location of the observer.

Notes:

Obscuration by earth is not modeled. In CBSKY4, this input is only used for time conversions.

[positional] positions

Summary:

Definition:	Defines the algorithm used for object coordinate computation.
Valid:	Apparent, Astrometric, Geometric
Default:	Astrometric

Description:

The position keyword defines the algorithm used for object coordinate computation.

Position Keyword	**Meaning**
Apparent	Apparent positions use the mean equinox and epoch of the observation. The reference_frame is given as True.
Astrometric	The positions are referenced to a standard reference_frame or equinox such as J2000, B1950, B1900, etc.
Geometric	Geometric coordinates are positions of objects without light-time corrections or aberrations.

Notes:

•

[positional] reference_frame

Summary:

Definition:	Define the location of the equinox.
Valid:	J2000 B1950 True
Default:	J2000

Description:

The equinox keyword sets the location of the Aries point or Vernal equinox location. By convention, the equinox location is the origin of ecliptic and equatorial coordinate systems. In ecliptic and equatorial coordinate systems, the longitude or Right Ascension is the measure of degrees or hours from the Aries point (Vernal equinox location). These coordinate systems are referenced to the center of the earth and the location of the Earth's orbit around the sun (ecliptic) and/or the location of the Earth's North Pole (equatorial). Planetary orbits drift with respect to the "fixed" stars. The Earth's spin precesses and nutates, thus changing the location of the North Pole with respect to the "fixed" stars. A new standard is set every 50 years to define the location of the Vernal equinox so that charts may be printed, and catalogs may be compiled in a Right Ascension and Declination coordinate system.

When the equinox is J2000 then the coordinate system is based on the J2000.0 system. When the equinox is B1950, then the coordinate system is based on the B1950.0 system. When the equinox is TRUE, then the coordinate system is based on the equinox of the date of observation.

Equinox Name	Julian Date of Equinox	Description
J2000	2451545.0	A coordinate system based on the J2000.0 system.
B1950	2433282.423	A coordinate system based on the B1950.0 system.
True	computed by CBSKY4	A coordinate system based on the equinox of the date of observation.

Notes:

The equinox value is only relevant and used when the coordinate system is equatorial or ecliptic. For galactic coordinates, the IAU (International Astronomical Union) has defined transformations from galactic latitude and longitude to ecliptic coordinates in the B1950 system and to equatorial coordinates in the B1950 system.

[positional] reference_system

Summary:

Definition:	Define the reference system.
Valid:	GEOCENTRIC TOPOCENTRIC HELIOCENTRIC BARYCENTRIC
Default:	GEOCENTRIC

Description:

Select the reference system for position/geometry routines.

Notes:

6. IRAS Data Sets

The IRAS data products are detailed in the IRAS Explanatory Supplement (Beichman et al. 1988). These data sets include:

- The IRAS Point Source Catalog (PSC)
- The IRAS Reject File
- The Small Scale Structure Catalog (SSSC)

The IRAS Point Source Catalog (PSC)	The PSC is a catalog of bright stars (point sources) extracted from the IRAS survey. The PSC yields well-defined statistics of star distributions for the entire sky. To some extent it shows galactic structure, however, the confused regions, especially near the galactic center, are under-sampled. The PSC includes cataloged galaxies and quasars of 11444 sources known before the IRAS survey and can be used to determine the integrated colors of galaxies of similar morphology.
The IRAS Reject File	This file contains confirmed point sources that failed quality and/or confirmation tests required to be included in the PSC. It includes spurious and variable sources.
The Small Scale Structure Catalog (SSSC)	The SSSC contains extended source data with spatial scales from 2 to 8 arcmin. The 16740 sources, which include emission from many galaxies, compact HII regions, and planetary nebulae, are almost all in the galactic plane.
The Asteroid and Comet Survey	This product is the IRAS catalog of detections associated with the numbered asteroids and comets. At release date, it was the most complete set of data on the infrared signatures of small solar system objects.
The Zodiacal Observation History File	IRAS survey data were averaged to synthesize a 30" x 32" beam over 8 seconds of time. This has been used to construct models of zodiacal emission.
IRAS Additional Observations	This data is used to study specific celestial objects and their immediate surroundings.
IRAS Serendipitous Survey	This extracted observations of all the point sources in each field and enhanced the sensitivity of the measurements by co-adding overlapping fields.
IRAS Calibrated Reconstructed Detector Data (CRDD)	The CRDD, which is available only to IPAC, is the readout of the detectors. Cohen et. Al. (1992) used the data to perform Power Spectral Density (PSD) analysis of the structured sky.
IRAS Low Resolution Spectra (LRS)	The LRS is a database of spectral information from 7 to 23 μm for 5425 point sources.

7. Input Files for the Sample Imagery

Table 20: Input File for the Orion Image (Visible Band, Catalog Output)

```
[Path]
architecture = DOS
log_output = Orion_V.log
path = \CBSD4\dataout\CBSKY4\
code_path = \CBSD4\CBSD\CBSKY4
data_path = \CBSD4\CBSD\sky4data
verbose = YES

[CBSKY4]
catalog = YES
catalog_limit = 3
clouds = NO
count_statistics = YES
elementsfile = ELEM_IAH.DAT
errmap = NO
extinction = NO
extmap = NO
magnitude_limit = 15
map = YES
method = CENTER
nodesfile = NODE_IAH.DAT
real_stars = YES
seed = 346
statistical_stars = NO
x-axis = MAGNITUDES
y-axis = Cumulative

[convolution]
convolution = YES
point_spread_function = gaussian
psf_half_width = 1.1

[Image]
Image = YES
output_format = FITS
image_type = 4-BYTE REAL
image_projection = RECTANGULAR
x_column_pixels = 400
y_row_pixels = 500
pixel_size = 0.08
image_center_longitude_degrees = 82.5000
image_center_latitude = 5.0
units = W/CM2

[Positional]
observer_altitude = 0.0
observer_geographic_latitude = -10.166850
observer_geographic_longitude = 189.54477
Reference_Frame = B1950
coordinate_system = equatorial
positions = apparent
Reference_system = geocentric

[spectral]
start_wavelength = V
end_wavelength= V

[Time]
observation_date = 2 2 2000
observation_time = 0 0 0.0
```

Table 21: Input File for the Rho Oph Cloud (cloud only - no statistical or real stars)

```
[Path]
architecture = DOS
path = \CBSD4\dataout\CBSKY4
code_path = \CBSD4\CBSD\CBSKY4
data_path = \CBSD4\CBSD\sky4data
verbose = yes

[CBSKY4]
log_output = Cloud_RhoOph_05.log
map = no
real_stars = no
statistical_stars = no
clouds = yes
magnitude_limit =15.
seed = 346
method = CENTER
catalog = no
catalog_limit = 12
nodesfile = NODE_IAH.DAT
elementsfile = ELEM_IAH.DAT
extinction = NO
count_statistics = YES
x-axis = MAGNITUDES
y-axis = cumulative
errmap = no
extmap = NO

[convolution]
convolution = no
point_spread_function = gaussian
psf_half_width = 0.8888

[Image]
Image = YES
output_format = FITS
image_type = 4-BYTE REAL
image_projection = RECTANGULAR
;The image projection type, GNOMONIC. MOLLWEIDE, or RECTANGULAR
x_column_pixels = 400
y_row_pixels = 400
pixel_size = 0.15
image_center_longitude_degrees = 356.0
image_center_latitude = 13.50
units = W/CM2/SR

[Positional]
observer_altitude = 0.0
observer_geographic_latitude = 0.0
observer_geographic_longitude = 0.0
Reference_Frame = B1950
coordinate_system = galactic
positions = apparent
Reference_system = geocentric

[spectral]
start_wavelength = 12UM

[Time]
observation_date = 2 2 2000
observation_time = 0 0 0.0
```

Table 22: Input File for the Horizontal Galactic Slice (Statistical Stars)

```
 [Path]
architecture = DOS
path = \CBSD4\dataout\CBSKY4\Horizontal_Galactic_Slices_K\
code_path = \CBSD4\CBSD\CBSKY4\
data_path = \CBSD4\CBSD\sky4data
verbose = NO

[CBSKY4]
log_output = S8_M18.log
map = NO
real_stars = NO
statistical_stars = YES
clouds = YES
magnitude_limit = 18
seed = 346
method = CENTER
catalog = NO
catalog_limit = 10
nodesfile = NODE_IAH.DAT
elementsfile = ELEM_IAH.DAT
extinction = NO
count_statistics = YES
x-axis = MAGNITUDES
y-axis = cumulative
;y-axis = differential
errmap = NO
extmap = NO

[convolution]
convolution = NO
point_spread_function = gaussian
psf_half_width = 1.01

[Image]
Image = YES
output_format = FITS
image_type = 4-BYTE REAL
image_projection = RECTANGULAR  ;The image projection type, GNOMONIC. MOLLWEIDE, or RECTANGULAR
x_column_pixels = 720
y_row_pixels = 20
pixel_size = 0.5
image_center_longitude_degrees = 0.000000000
image_center_latitude = 15.000000000
units = W/CM2

[Positional]
observer_altitude = 0.0
observer_geographic_latitude = 0.0
observer_geographic_longitude = 0.0
Reference_Frame = B1950
coordinate_system = galactic
positions = apparent
Reference_system = geocentric

[spectral]
start_wavelength = K

[Time]
observation_date = 2 2 2000
observation_time = 0 0 0.0
```

Table 23: Input File for the Off-Plane Confused Region (B=3, L=0)

```
[Path]
architecture = DOS
path = \cbsd4\dataout\cbsky4\Ex_Method\
code_path = \cbsd4\cbsd\cbsky4
data_path = \cbsd4\cbsd\sky4data
verbose = YES

[cbsky4]
log_output = Vertices.log
map = NO
real_stars = NO
statistical_stars = YES
clouds = NO
magnitude_limit = 12
seed = 346
method = VERTICES
catalog = YES
catalog_limit = 2
nodesfile = NODE_IAH.DAT
elementsfile = ELEM_IAH.DAT
extinction = YES
count_statistics = YES
x-axis = MAGNITUDES
y-axis = Cumulative
errmap = NO
extmap = NO
spectral_type = 0

[convolution]
convolution = NO
point_spread_function = gaussian
psf_half_width = 1.01

[Image]
Image = YES
output_format = FITS
image_type = 4-BYTE REAL
image_projection = Rectangular
x_column_pixels = 500
y_row_pixels = 500
pixel_size = .02
image_center_longitude_degrees = 0
image_center_latitude = 3
units = W/CM2

[Positional]
observer_altitude = 0.0
observer_geographic_latitude = 0.0
observer_geographic_longitude = 0.0
Reference_Frame = J2000
coordinate_system = galactic
positions = apparent
Reference_system = geocentric

[Spectral]
start_wavelength = 12UM

[Time]
observation_date = 2 2 2000
observation_time = 0 0 0.0
```

8. Response Function Parameters

Values for IRAS and ground-based bands (L, M, 8.7, N, 11.7, and Q) are from Cohen et al. (1992), Campins et al. (1985), and Rieke, et al. (1985). Values for MSX are from Cohen (1997, 1998). Johnson UBVRI fron Price and Murdock (1985). DIRBE from (Hauser et al., 1998).

Table 24: Listing of filter functions, CBSD file name, and photometric parameters.

Filter	file	Bandwidth (μm)	band_center (μm)	flux_mag_zero (Jy)	flux_mag_zero ($W/cm^2/\mu m$)
Normal Eye	Norm_eye.dat				
Johnson U	sjohn_u.dat	0.068	0.365		4.27E-12
Johnson B	sjohn_b.dat	0.098	0.44		6.61E-12
Johnson V	sjohn_v.dat	0.089	0.55	3540	3.72E-12
Johnson R	ajohn_r.dat	0.22	0.70		1.74E-12
Johnson I	sjohn_i.dat	0.24	0.88		8.32E-13
IRAS Band 1 (12 μm)	IRAS1.dat	6.47	12.0	40.141[a]	8.363E-17
IRAS Band 2 (25 μm)	IRAS2.dat	10.75	25.0	8.886[a]	4.265E-18
IRAS Band 3 (60 μm)	IRAS3.dat	30.96	60.0	1.447[a]	1.206E-19
IRAS Band 4 (100 μm)	IRAS4.dat	33.33	100.0	0.421[a]	1.264E-20
IRTF L (3.54 μm)	IRTF_L.dat	0.97	3.547	276.4[b]	6.590E-15
IRTF M (4.80 μm)	IRTF_M.dat	0.60	4.769	159.7[c]	2.107E-15
IRTF 8.7 (8.7 μm)	IRTF_087.dat	1.16	8.756	49.98	1.955E-16
IRTF N (10.1 μm)	IRTF_N.dat	5.0	10.427	35.21[d]	9.631E-17
IRTF 11.7 (11.7 μm)	IRTF_117.dat	1.16	11.653	28.56	6.308E-17
IRTF Q (20 μm)	IRTF_Q.dat	10.0	20.0	9.4	7.182E-18
MSX Band A	MSX_A.dat	3.362	8.276	58.485 ±0.9	2.438E-16
MSX Band B1	MSX_B1.dat	0.1036	4.294	194.59 ±3.6	3.165E-15
MSX Band B2	MSX_B2.dat	0.1794	4.352	188.84 ±3.3	2.989E-15
MSX Band C	MSX_C.dat	1.7205	12.126	26.506 ±0.5	5.382E-17
MSX Band D	MSX_D.dat	2.2344	14.649	18.288 ±0.6	2.545E-17
MSX Band E	MSX_E.dat	6.244	21.336	8.80 ±0.7	5.694E-18
DIRBE Band 1	DIREBE01.DAT	0.3013	1.25		
DIRBE Band 2	DIREBE02.DAT	0.3657	2.20		
DIRBE Band 3	DIREBE03.DAT	0.9140	3.50		
DIRBE Band 4	DIREBE04.DAT	0.6605	4.90		
DIRBE Band 5	DIREBE05.DAT	7.0	12.0		
DIRBE Band 6	DIREBE06.DAT	8.805	25.0		
DIRBE Band 7	DIREBE07.DAT	29.446	60.0		
DIRBE Band 8	DIREBE08.DAT	33.3698	100.0		
DIRBE Band 9	DIREBE09.DAT	41.1936	140.0		
DIRBE Band 10	DIREBE10.DAT	99.2086	240.0		

[a] (Beichman et al. 1988, pg VI-21 gives 28.3, 6.73, 1.19, and 0.43 respectively)

[b] (Campins et al. 1985 gives 288 ±6)

[c] (Campins et al. 1985 gives 170 ±8)

[d] (Reike et al. 1985 gives 36.0 ±1.2)

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